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A Manual of Laws, Regulations, and Institutions for Control of Ground Water Pollution

National Water Well Association, Worthington, Ohio

Prepared for

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A MANUAL OF LAWS, REGULATIONS, AND INSTITUTIONS FOR CONTROL OF GROUND WATER POLLUTION

JUNE 1976

FINAL REPORT

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Ground water is a natural resource that can be expected to become increasingly valuable as a water source. Unattended, it may become extensively polluted, resulting in great loss of value. The manual covers ground water pollution problems broadly and is intended for use by the layman or by a State agency interested in examining State laws and regulations affecting this resource. The manual describes ground water resources and sources of pollution, then surveys existing regulations that affect ground water quality. Suggestions for ground water pollution control are supplied, primarily in the form of regulatory provisions. These suggestions are offered as guides for selection or modification by a State according to its particular needs, since no single program of ground water management would be applicable in all locations.

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INTRODUCTION

The Federal Water Pollution Control Act Amendments of 1972 (Public Law 92-500) affected state water pollution control programs to an unprecedented degree. That law was directed almost wholly at surface water problems, however, and affected ground water only in an incidental fashion. The Safe Drinking Water Act of 1974 (Public Law 93-523) has authorized a similarly significant federal concern with state programs for the control of ground water quality. It does not affect all aspects of ground water quality control. It is primarily directed at protection of drinking water supplies. The law authorizes federal establishment of minimum requirements for a state program where an underground injection control program is required to assure that such injections will not endanger drinking water sources.

The following manual covers ground water pollution problems broadly. It does not limit itself to the specific subject areas of the Safe Drinking Water Act and should not be confused with the Underground Injection Control Program promulgated under the Safe Drinking Water Act. It is by design not comprehensive in detail, since it is intended for use by the layman as much as by a state agency interested in examining its state laws and regulations. The manual is intended for use on the state and local levels by people concerned with ground water quality. It is not a report of problems; its purpose is, rather, to supply a range of suggestions for ground water pollution control, primarily in the form of regulatory provisions.

Ground water is a vast, natural resource that can be expected to become increasingly valuable as a water source throughout most states. The recognized danger that stimulated the production of this manual is that ground water, unattended, may become extensively polluted, resulting in great loss of value. Unlike surface water, ground water quality cannot be "corrected" by pollution controls applied after the pollution has occurred. Also, unlike surface water, there is no single, simple approach to prevent ground water pollution. Activities that pollute ground water, and the regulatory techniques necessary for their control, are many and highly varied.

The manual describes ground water resources and sources of pollution, then surveys existing regulations that affect ground water quality. This survey is organized according to "control points" at which regulatory effort may be directed to control ground water polluting activities. For a bird's-eye view of the scope of regulatory activity affecting ground water, the reader's attention is directed to this list of control points on page II-2.

The manual proposes a number of statutory provisions that will enable a state to protect ground water, and presents guidelines for the development of regulations designed to prevent pollution of ground water. It discusses manpower requirements and other aspects of implementation of the statutes and regulations proposed by the manual. These chapters on regulation of activities are the central feature of the manual. They are offered as guides, or starting-points, for selection or modification by a state according to its particular needs. Some are in the alternative, and some contradict other regulations proposed. They are presented in the belief that no single manual of regulations can be written that would be applicable to all states, not only because of the hydrologic complexity of this country, but also because of the economic, social, legal, and political diversity that such regulations must reflect in order to be workable in different settings.

Useful as it is hoped this manual may be to a state concerned about protection of its ground water, it cannot address itself to all the essentials for a good ground water program. Effective regulation presupposes an adequate base of background water data and a continuing program to collect it, which this manual does not presume to describe. Neither does it attempt to instruct a state as to how its agencies should be organized for optimum effect. Even in proposing regulations, humility dictated that the manual address itself to regulation of current operations, omitting correction of past faults, such as past unsupervised abandonment of water wells and oil and gas wells, unreclaimed mines, and all the other historic trauma to the earth that cause present ground water pollution but which will at best yield only to special projects where technological solutions and a source of adequate funds tend to be the critical constraints.

This document is not a proposal to affect water-rights laws. Complete ground water protection must include controls on the use of water under particular circumstances -- reference is made in the manual to the propriety of such controls in effecting ground water pollution control. However, control or withdrawal of water for the purpose of allocating property rights in water is considered to be a separate subject best considered by individual states, in accordance with their needs.

It will be evident to the ground water expert that the manual is not highly technical. It does not purport to educate the expert, other than to offer him a compendium of regulatory concepts. It assumes that many people other than those professionally qualified to deal with ground water are interested in its protection, and will be involved in programs to protect it.

At the time of extensive new regulation of activities affecting the environment, regulatory proposals such as those in this manual can be expected to meet with considerable indifference or hostility. Those responsible for industrial production, especially, cannot be expected to welcome regulation; survival in the American economy, within existing regulatory structures, is not easy. At the same time, careless pollution of ground water can have future effects that may be unrecognized in their eventual extent and severity. It is hoped that the validity of both these positions will be recognized in application of the materials in this manual.

The manual is timely for the fact that the effectiveness of other regulations has made methods of waste disposal that endanger ground water quality relatively more economical, increasing the likelihood that ground water pollution will occur.

There is no intent in offering this manual to foster federal control over ground water. To the contrary, the purpose of the manual is to enhance knowledgeability in the states, and thus to enable establishment of adequate ground water protection programs on the state or local level.

The manual is offered not in a spirit of eagerness to regulate, but simply in the belief that ground water is a vital resource that is especially susceptible to degradation because it is difficult to protect and easy to ignore.

EPA REVIEW NOTICE

This report was prepared under a contract financed by the U.S. Environmental Protection Agency and is approved by the Agency for publication as an important contribution toward control of ground water pollution. Publication approval does not necessarily signify that the contents reflect the views and policies of the Agency. The mention of trade names or commercial products does not constitute endorsement or recommendation for use.

CHAPTER I

THE HYDROLOGIC FRAMEWORK

This chapter describes the hydrologic cycle and the nature and characteristics of ground water, with emphasis on water quality and the various ways in which pollution of ground water occurs. It presents the generalized physical aspect of ground water pollution in preparation for the discussion of existing and proposed guideline regulations for the control of ground water pollution in subsequent chapters.

The chapter begins with a presentation of misconceptions concerning ground water. While this is not the usual textbook approach to introducing the subject of ground water, it was felt to be pertinent in this case, because the present status of regulation and the problems that exist concerning ground water are to a great extent attributable to its inadequate perception, which results from the fact that ground water cannot be directly observed. This is not intended to suggest that existing regulations are based upon misconceptions (although some court decisions have been so based); it is intended only to underline the fact that in the case of ground water, as different from surface water, perception and recognition of facts, and thus application of remedies, come slowly.

The information in this chapter was obtained from a variety of sources, some published, some unpublished, albeit only a few are cited in the bibliography. Many of the situations and hydrologic concepts described are generalized, and their details thus may not be valid for many specific applications. The chapter is not intended to be an authoritative work in ground water hydrology, but rather an introduction to the subject for individuals with little or no hydrologic training.

MISCONCEPTIONS CONCERNING GROUND WATER

Ground water is neither mysterious nor occult, it does not occur in underground lakes or rivers, and spring water is not synonymous with purity. Nevertheless, there is widely-held popular belief to the contrary. These and other misconceptions of the nature and behavior of ground water are examined in the following material.

Misconception:	Ground water often occurs in underground lakes and rivers.
Fact:	Bodies of ground water generally bear little resemblance to surface water bodies.

The erroneous concept of huge underground lakes and rivers is based upon fact: in areas where limestone forms the major aquifers, the water may flow in large underground openings, such as caves and solution channels. In one sense these large openings, which are relatively rare, resemble rivers and lakes. In Mammoth Cave, Kentucky, for example, blind fish inhabit a stream that flows through the cave. In the vast majority of cases, however, ground water occurs in rock formations that have a sufficient number of interconnected openings (permeable material) for the water to pass through them. Not uncommonly, these aquifers (water-bearing deposits) are connected for hundreds or thousands of square miles. Along many river valleys, the floodplain deposits consist of permeable sand and gravel. In such cases, the ground water may flow generally in the same direction as the surface stream. This large volume of slowly-moving ground water adjacent to the stream may flow in a direction different from the regional underground flow in nearby areas. This does not mean that the flow characteristics of the ground water in the stream-side deposits are in any manner similar to those of a surface stream.

During the last Ice Age, when glaciers advanced across the northern part of the United States, many of the then existing stream channels were filled and the streams were forced to develop other courses. Many of these now-buried river valleys contain great quantities of ground water, but the enclosed water cannot be likened to an underground river.

Misconception:	Ground water is mysterious and occult.
Fact:	Natural Laws control the occurrence and movement of ground water and therefore its behavior is predictable.

Before the development of scientific techniques of ground water hydrology, the natural laws controlling water movement were unknown. This led to the concept, preserved in case law, that the occurrence and movement of water in the ground is mysterious and occult -- i.e., that the principles of its behavior cannot be known. In fact, using well-established natural laws and the relevant hydrologic data, the quantity and quality of ground water are subject to prediction both in space and in time.

Misconception: Water rushes so rapidly underground that its presence can be detected by listening.

Fact: In most cases ground water flows only a few feet per year.

Some people believe they can detect the presence of large quantities of water underground merely by placing an ear to the earth and listening for the sound of rushing water. This is not possible because ground water moves very slowly through the earth, in most cases only a few feet per year. Locally, it may flow very rapidly in limestone terrain characterized by large openings, such as caves, but such conditions are rare. Ground water velocity is of particular importance in water-pollution problems. Due to its slow rate of movement, an area once polluted may remain unusuable for years. It is primarily for this reason that disposal of wastes on and in the ground must be closely regulated.

Misconception: Ground water removed from the earth is never returned.

Fact: Ground water is a renewable resource.

In most parts of the country, water removed from the ground is constantly replaced. Thus, ground water is a renewable resource, although in some places the rate of replenishment is very slow. In some arid and semiarid regions, a slow rate of replenishment is far exceeded by the rate of ground water pumping, resulting in some cases in serious problems of ground water mining.

Water constantly seeps into the ground. Areas where this occurs are called recharge areas; they include virtually the entire land surface, although recharge rates vary greatly. Some types of soil accept water much more rapidly than others -- for example, the rate of infiltration (the rate at which water seeps into the ground) through sandy soil will be much greater than through a heavy clay soil. Relatively high rates of recharge (infiltration) may occur in sandy or gravelly areas and along river flood plains where the water table has been lowered by pumping.

Areas with high rates of recharge should be carefully managed for two major reasons. First, they allow replenishment of underlying groundwater reservoirs (aquifers) and, second, water-soluble waste products stored in these areas may infiltrate and pollute the underground supply. Consequently, areas of high recharge must be protected in order to maintain the quantity of water in storage and to protect its quality.

Misconception:	Ground water migrates thousands of miles through the earth.
Fact:	Most ground water is replaced in the near vicinity of its withdrawal.

Much of the water in a ground water reservoir infiltrates within a radius of a few tens of miles of where it is found. It has not travelled in the ground for thousands or even hundreds of miles. There are no underground rivers transporting great volumes of pure water from Canada to Minnesota, Virginia to Florida, or from the Rocky Mountains to Iowa or other Great Plains states.

Misconception:	Ground water is not a significant source of supply.
Fact:	The amount of ground water in storage dwarfs our present surface supply.

Ground water is commonly considered an insignificant source of supply. The fact is, however, that in the United States the quantity of water in underground storage is 2,000 to 3,000 times larger than the amount at any moment in all the lakes, streams, and rivers combined. At the same time, ground water is usually cold, of a nearly constant temperature, free of sediment, and of generally good quality. The major feature of ground water is its widespread occurrence -- it commonly provides a reliable and economical water supply for many kinds of activities for which surface water supplies would be uneconomical or infeasible.

In 1970, the United States was using more than 370 billion gallons of water per day. Of this amount, about 20 per cent was ground water. About a third of all public supplies and about 96 per cent of all rural domestic supplies are derived from wells. About 25 per cent of the water used for irrigation is ground water. Were it not for huge underground reservoirs, many irrigation schemes in the arid and semi-arid regions of the United States could not long continue. Ground water makes possible agriculture and industry alike because commonly it is available at the point of use and does not require transportation over long distances.

Misconception: There is no relationship between ground water and surface water.

Fact: Ground water provides much of the flow of streams; lakes and swamps are merely windows in the water table.

It is commonly believed that ground water and surface water represent isolated systems. Consider, however, a stream in late summer. Although it may not have rained for several days or possibly even weeks, there may still be a considerable flow in the stream. Obviously, this water could not have been derived from the surface runoff of rainfall. In large part the streamflow represents water that has flowed from the ground into the stream channel. In other words, the low flow of a stream may be derived entirely from ground water discharge. In addition, wells located near a stream may cause water to flow from the stream to the well thus depleting the surface flow.

During low-flow conditions, the chemical quality of the stream is similar to that in adjacent aquifers, but during periods of surface runoff and precipitation, the stream quality is considerably different. In some places, the quality of surface water deteriorates during the late summer and fall because adjacent ground water reservoirs are polluted and these polluted ground waters provide the stream flow. It is evident that one needs to consider not only waste disposal directly into a stream but also the disposal of water-soluble material on the land surface, particularly in recharge areas. In other words, there is often a close interrelationship between surface water and ground water and one cannot be managed without consideration of the other.

Misconception:	The water table is falling throughout the country.
Fact:	Although in a few areas the water table has declined significantly, in most places the water table rises and falls with climatic vagaries.

Not uncommonly one hears that "the water table is falling". During periods of drought, when water demands increase substantially and withdrawals exceed the rate of natural recharge, the water table or water-pressure surface may decline. In most cases, the decline is temporary and the water level recovers when rainfall returns to normal. A similar problem of declining water levels exists in particular areas where municipalities or large industrial complexes use ground water, and in areas of extensive irrigation. This is because the rate of ground water pumping over long periods may far exceed the natural rate of replenishment (recharge) within the area of supply. Most of these areas are small and unmanaged although in some instances the declines are based on sound management concepts. Generally throughout the country, ground water levels simply rise and fall with the seasons in relation to precipitation, temperature, and local land-use practices.

Misconception: The water level in a well remains constant.
Fact: The water level must decline in the vicinity of a pumping well.

If the proud owner of a new well believes there is no water-level lowering or drawdown when his pump is operating, he is mistaken. There must be a water-level decline in the vicinity of a pumping well in order to induce water to flow to the well. In highly permeable formations, such as limestone caverns or sand and gravel deposits, the amount of drawdown may be slight. With increasing withdrawal rates, however, the drawdown increases -- around high-yield wells, water-level lowering in the area of influence may extend outward for miles. Other phenomena also cause the water level in a well to fluctuate, including seasonal influences on recharge and discharge, and loading effects.

Misconception: Spring water is synonymous with exceptional quality.
Facts: Springs are points where ground water is discharging, but they are easily polluted.

Various product advertisements assert that spring water has exceptional taste, purity, and perhaps medicinal properties. They may also imply that well water is of unacceptable quality. A spring, however, is merely a point where ground water is discharging at the land surface. It has nearly the same quality as nearby wells. On the other hand, springs lack some of the protection afforded by wells and can be easily polluted. Well water is biologically pure (free of pathogens) except when polluted by sewage or certain other wastes, the sources of which generally lie in the near vicinity.

Misconception:	All well water is naturally of drinkable quality.
Fact:	The natural mineralization of ground water generally increases with depth; eventually a point is reached where it is no longer potable because of naturally-occurring minerals dissolved from the rocks through which the water flows.

Not all ground water is drinkable. Lying at varying depths down to several hundred feet is the fresh-saltwater interface, a zone of variable thickness where the dissolved mineral content exceeds 1000 mg/l Below this interface, the mineral content of the water increases substantially -- at greater depths it may be so mineralized that it is considered a brine. Wells whose total depth approaches the fresh-saltwater interface eventually suffer from deteriorating quality due to the upward migration of salt water as fresh water is removed. In coastal areas, overpumping or drainage of fresh water may cause migration of sea water into the aquifer. Adequate water-management programs can substantially reduce problems caused by migrating highly-mineralized water.

Misconception:	Since ground water can't be seen, nothing is happening to it.
Fact:	We do not know the extent of ground water pollution, but from available information we know that the threat of its widespread pollution is substantial.

If an individual laid a raw sewage discharge line into a lake, it is unlikely that he would decide to withdraw his drinking water from a surface intake only 25 feet away. The potential health problem would be easily recognized. Because ground water cannot be seen, however, such an error may not be evident to the user of a well. Where a cesspool or septic-tank drain lay within 25 feet of a well, the potential health problem (effluent flowing directly into the well) might not be recognized.

Karubian (1974) examined the petroleum, pulp and paper, and primary metals industries in the United States in an attempt to estimate the effect of these activities on ground water pollution. These industries produce a large quantity of waste water, much of which is stored in unlined basins and lagoons. The liquids leak from the containment structures and pollute ground water. It was estimated that the total leakage during 1973 from these structures was 192,815 acre-feet from primary metals industries, 76,335 acre-feet from petroleum refining, and nearly 134,000 acre-feet from the pulp and paper industry. Thus the total quantity of leakage from these three industries alone amounted to more than 403,000 acre-feet* of waste water. The pollution is occurring underground, is hidden from view, and is not easily recognized. The problem is nonetheless significant, and for the most part will be impossible to correct.

Leaky sewers in cities and septic tanks and cesspools in surburban and rural areas probably add far more pollution on a national scale than do the above-cited industries. One must also consider the major contribution of pollutants from tens of thousands of sewage

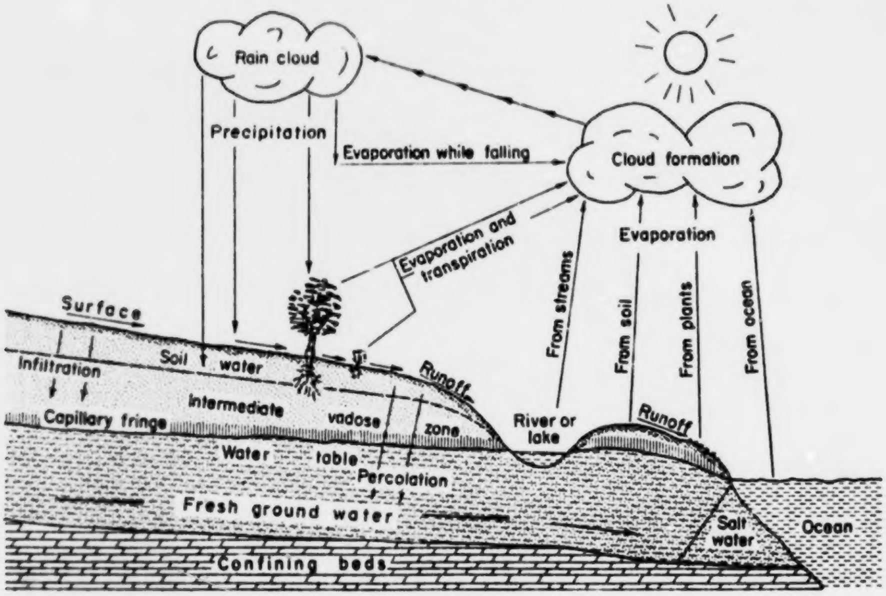
Rain cloud
Precipitation
Evaporation while falling
Cloud formation
Evaporation and transpiration
Evaporation
From streams
From soil
From plants
From ocean
Surface
Soil water
Infiltration
Runoff
Intermediate vadose zone
Capillary fringe
Water table
Percolation
River or lake
Runoff
Fresh ground water
Salt water
Ocean
Confining beds

Figure 1. Schematic Diagram of the earth's water cycle -- the hydrologic cycle.
(From Johnson, 1966, p. 16)

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*An acre-foot of water equals 325,851 gallons or 43,560 cubic feet.

lagoons at municipal or semi-public sewage-treatment plants throughout the country, as well as the potential of similar polluted water derived from irrigation using sewage sludge and effluent liquid.

THE HYDROLOGIC CYCLE

INTRODUCTION

The hydrologic cycle describes the movement of water from the atmosphere, to and into the ground and streams, and its eventual return to the atmosphere. An intimate part of the hydrologic cycle is the geochemical cycle, which determines the resultant quality of water that will occur at any point in time or space. Some parts of the hydrologic cycle can be managed, others can be subdued to some extent, but with others, man-made controls are not possible.

In order to understand the fundamentals of ground water hydrology and water quality, a basic understanding of the hydrologic cycle is necessary. Although complex in detail, the hydrologic cycle can be visualized as a water droplet taking any one of the several paths shown in Figure 1. The following material describes the major parts of the cycle, with emphasis on the ground water phase and its relationship to surface water.

PRECIPITATION

The world's oceans and other major bodies of water serve as huge reservoirs from which large quantities of water are evaporated each day.

Although much of this moisture immediately returns to its source as precipitation, a large quantity is carried by the planetary wind system to the land masses where it falls as precipitation.

Only part of this precipitation reaches the land surface because some evaporates while falling. Some of the precipitation that reaches land surface quickly returns to the atmosphere via evaporation, or runs off to watercourses, some replaces the soil-moisture deficiency, and the remainder "infiltrates" to become ground water. During or immediately following a period of precipitation or snowmelt, stream flows increase in response to the water added to the channel by surface runoff; at other times streams may flow only because ground water discharges into them. Variations in stream flow and the amount of water that infiltrates into the ground are directly related to variations in precipitation.

Different types of hydrologic problems and, consequently, management techniques, are directly related to the distribution of precipitation. For example, much of the western half of the United States exclusive of mountain ranges has less than 20 inches of precipitation annually, yet the rate of potential evapotranspiration exceeds this amount, causing a water deficiency. Therefore, the rate of replacement of water pumped from the ground can be extremely slow, leading to severe shortages of ground water, particularly in irrigated areas.

Another problem in arid and semiarid regions is that water resources tend to be more highly mineralized because of numerous soluble rocks, a lack of dilution, and because evaporation, which leads to increased mineralization, is generally great.

SOIL MOISTURE

Picturing the soil as a sponge, water will not flow downward through it until nearly all of the interconnected open spaces are filled with water. If the sponge is covered with a blotter, analogous to a layer of clay overlying sandy material, most of the water falling on it will flow off and very little will seep into the sponge. The amount of infiltration through the soil-sponge is dependent upon several primary factors, including topography, rock type, and vegetative cover. The greatest amount of infiltration occurs during long, low-intensity rains on fairly level sandy or gravelly soil; the least amount on steeply-sloping, bare, fine-grained soils such as clay (Figure 2).

Following a wet period, the soil-moisture content decreases as part of the water moves deeper into the ground and much of that retained in the soil is either evaporated or removed by plants (transpiration).

In arid regions, the water table may lie 2,000 feet or more below land surface because of the low rate of precipitation and the high rate of evapotranspiration, which use up the available precipitation before it can percolate to the ground water reservoir. Consequently, recharge to deep zones may be very small, occurring in relatively few places or under unusual hydrologic conditions.

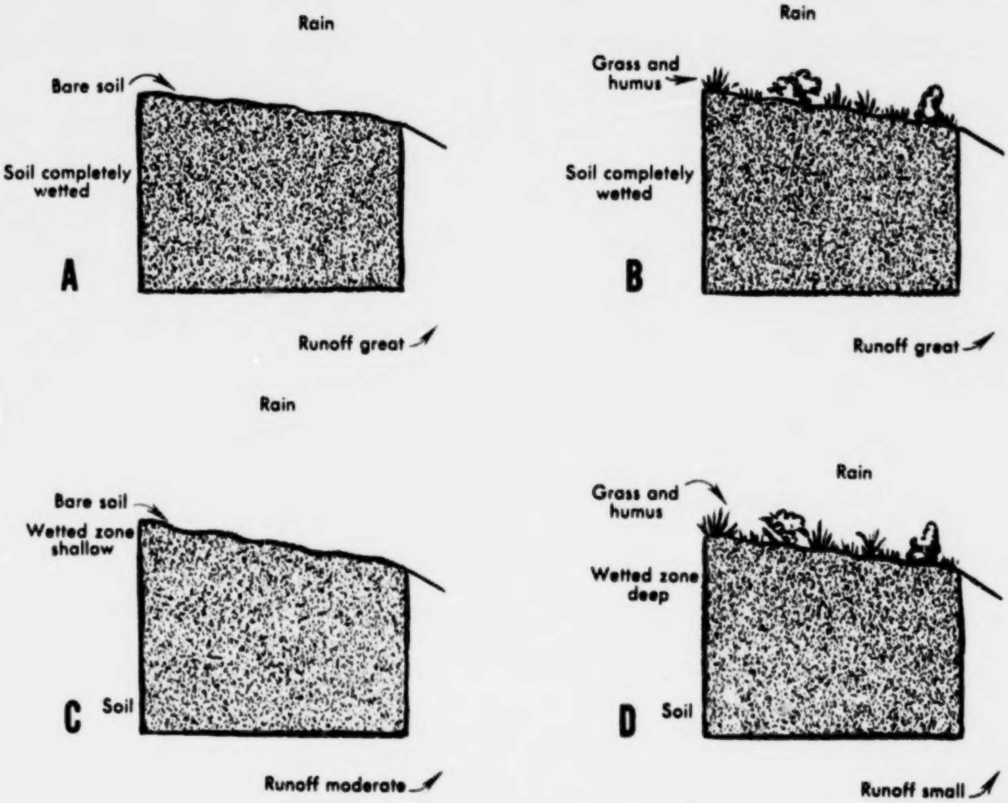

Rain
Bare soil
Soil completely wetted
A
Runoff great
Rain
Grass and humus
Soil completely wetted
B
Runoff great
Rain
Bare soil
Wetted zone shallow
C
Soil
Runoff moderate
Rain
Grass and humus
Wetted zone deep
D
Soil
Runoff small

Figure 2. Runoff from bare and vegetated surfaces under different conditions of soil moisture.
(From Leopold and Langbein, 1960, p. 28)

Several techniques have been tried in an attempt to manage (either to conserve or reduce) soil moisture; these have met with some success on a regional scale. There are no legal controls dealing with soil moisture; in law it is considered part of the land, and not a controllable water resource. From a hydrologic viewpoint, however, the soil-moisture content is one of the most significant natural controls on the availability of both ground water and surface water. It regulates the amount and rate of natural replenishment of ground water reservoirs, for until the soil-moisture deficiency has been satisfied no ground-water recharge can occur. It affects streamflow, because moisturedeficient soil has first demand on much of the overland flow to streams, and to the extent that soil-moisture deficiency deters ground water recharge, ground water's function of supplying the base flow of perennial streams may be impaired.

EVAPOTRANSPIRATION

The greatest share of the precipitation that reaches land surface is returned to the atmosphere by evaporation, and transpiration by plants. That quantity transpired by plants has been used during their normal biologic processes (metabolism). The water is considered to be "wasted" only if it is transpired by unwanted plants -- even then it is not used up, but is merely put back into the atmosphere for later return as precipitation.

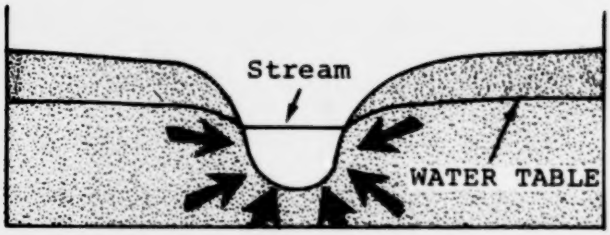
As is true with precipitation, water losses by evaporation range widely in time and place. Unfortunately, the greatest amount of evaporation occurs in arid and semiarid regions -- regions that can least afford the loss. Water lost by evaporation from surface reservoirs in arid regions amounts to millions of acre-feet per year, and not only greatly reduces the quantity of water available, but also leads to increased mineral content of the water remaining.

STREAMFLOW

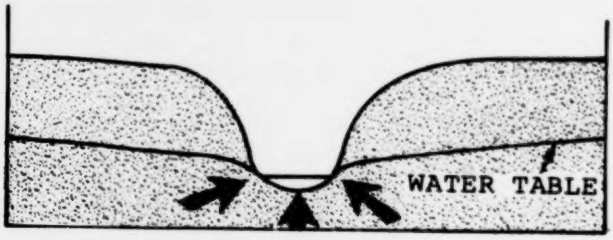
The flow of water in streams ranges within wide limits, being largely controlled by precipitation. Perennial streams are those that flow throughout the year; their discharge rates vary seasonally and with precipitation. Intermittent streams generally flow only during that part of the year when the water table is above the bottom of the stream bed or when they receive surface runoff. As the water table declines, streamflow decreases; eventually certain reaches of the channel may become dry. Ephemeral streams -- numerically the most common -- flow only during and immediately after precipitation or snow melt. Water entering the dry or nearly dry channels of ephemeral streams commonly seeps into the ground, resulting in ground water recharge.

The largest amount of precipitation in the coterminous United States occurs in the Pacific Northwest and in the eastern half of the country, resulting in longer periods of high soil-moisture content, greater prolonged rates of infiltration, and greater runoff into streams in these areas. Here also lie the major perennial river systems, which discharge to the surrounding oceans many times more water than do the drainage ways in the arid and semiarid regions of the Midwest and Western states.

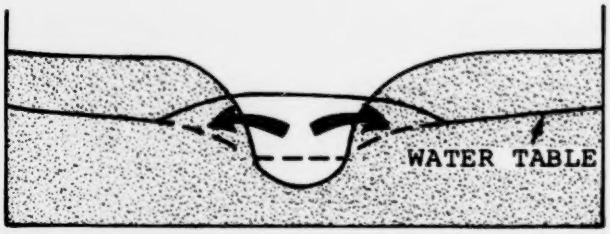
Water in a stream originates as surface runoff, ground water discharge, municipal-industrial-agricultural effluent, or direct precipitation into the channel. Perennial streams occur in those areas where adjacent saturated deposits drain into the channels (Figure 3). It is this release of ground water that provides much, or sometimes all, of the stream's flow. As the adjacent ground water level declines, there is a concomitant decrease in stream flow. Drier regions are charac-


Stream
WATER TABLE

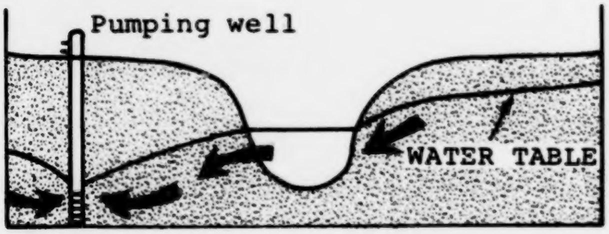
A. Streamflow sustained by ground water inflow; high water table, large stream discharge.


WATER TABLE

B. Stream during low-flow conditions; low water table, low stream discharge.


WATER TABLE

C. During periods of flooding, water may flow from the stream into the ground.


Pumping well
WATER TABLE

D. A well pumping near a stream may cause water to flow from the stream into the ground (induced ground water recharge).

Figure 3. Relation between ground water and surface water.

terized by low sustained flows, or, if the water table is below the stream, no flows except during periods of large snowmelt or heavy rainfall. During high flows, such as floods, water may migrate from the stream into the ground (Figure 3). Pumping wells may cause stream water to infiltrate due to a lowering of the water table (Figure 3).

Because ground water is a major source, the quality of the stream water reflects the quality of adjacent and upbasin ground water resources. Most water-pollution control legislation is directed at surface water, with ground water pollution being largely ignored. Such legislation also fails to control surface water pollution that results from the discharge of polluted ground water.

Surface water can be controlled by various engineering structures and management techniques. At least to some extent the quality of surface water can be managed by adequate effluent standards, by control over ground water pollution, and by land-use management.

GROUND WATER

AQUIFER FRAMEWORK

Rocks that form aquifers can be divided into two major types: (1) igneous and metamorphic and (2) sedimentary. Igneous and metamorphic rocks, such as granite, slate and marble, are hard and dense earth materials formed by the solidification of molten rock or by temperature, pressure, and chemically-active fluids acting upon and changing pre-existing rocks. Sedimentary rocks, such as shale, limestone, and sandstone, were formed by deposition of material by siltation, transported in suspension (generally by water) or in solution. Sedimentary rocks are either consolidated or unconsolidated.

A. Igneous and Metamorphic Rocks

Ground water is commonly hard to find in those regions where igneous and metamorphic rocks are at or near land surface, because there is a general lack of open spaces in these rocks that could contain water. Water supplies obtained from them are generally inadequate for large municipal and industrial supplies. There are some exceptions; for instance, large quantities of water may occur in fault zones. Water in igneous and metamorphic rocks is commonly limited to fractures (joints or faults) in the rocks, although in some places substantial quantities may be stored in a thick zone of weathered rock. Igneous and metamorphic rocks are generally very hard and are both difficult and expensive to drill.

Some volcanic rocks, particularly lava flows, contain a great number of interconnected openings and hence are highly permeable. They may enclose a weathered zone, a zone characterized by coarse-grained sediments, or there may be permeable areas caused by fractures, lava tubes, or vesicles created by gas bubbles when the lava was in its liquid form.

The quality of water in igneous and metamorphic rocks is generally excellent in that it has a very low dissolved-mineral content. On the other hand, it is easily polluted because the water-producing fractures may be interconnected and open to the surface where little or no filtering of the water through sediments can take place. Filtering through soil or sandy material tends to remove biological material and some, but certainly not all, chemicals. Special care must be taken to preserve the natural quality of water found in igneous and metamorphic rocks, particularly since large supplies are difficult to locate.

B. Sedimentary Rocks

Sedimentary rocks not only provide the greatest amount of water to wells, they also store huge volumes. Sedimentary rocks may be subdivided into consolidated and unconsolidated deposits. Consolidated deposits (rocks) are relatively hard and dense due to compaction or cementation of the grains. Typical examples include shale (compacted) silt and clay), siltstone (compacted silt), sandstone (cemented grains of sand), and carbonates, such as limestone and dolostone. Unconsolidated sediments consist of uncemented material such as clay, silt, sand and gravel. These deposits are generally neither hard nor dense.

Consolidated Rocks

Consolidated rocks, being hard and dense, in most cases provide only small to moderate yeilds to wells. This is largely due to the small storage capacity between the individual grains, the tendency for very small grains to hold the water against the force of gravity, and to relatively poor connection between openings (low permeability). As with igneous and metamorphic rocks, many consolidated sediments contain an abundance of fractures or solution openings that store and yield large supplies of water. Even though many of these rocks, for example siltstone and shale, may not provide large yields to wells, they are important hydrologically because large quantities of water may slowly drain from them into adjacent aquifers, increasing the potential for development. They also may serve as confining beds and reduce the amount of leakage from one aquifer to another.

Deposits of shale commonly contain an abundance of openings (high porosity) but they are not interconnected and thus have a low permeability. They provide a vast storage space, but yield water only by slow drainage. Moreover, the stored water is commonly highly mineralized.

Porosity and permeability of carbonate rocks such as some dense or chalky limestones is generally very low. Openings that do exist may be very large, occurring along fractures and solution openings along bedding planes and joints. Solution openings may slowly migrate upward, eventually leading to surficial collapse, the formation of sinkholes, and sometimes the local disappearance of surface streams. In carbonate terrain, ground water does not necessarily flow perpendicularly to water-level contours since it tends to follow the solution openings. Yields of wells range from very high to extremely low depending on the size and interconnection of openings penetrated by the well bore.

Unfortunately sinkholes, disposal wells, pits, and quarries in permeable limestone are used in many areas for the disposal of storm waters, garbage, and other wastes. These disposal techniques permit direct aquifer pollution. Because little or no filtering of the water is available as it moves through the large openings in limestone, it is highly susceptible to pollution. In coastal areas, overpumping of aquifers has allowed sea water to intrude and pollute the ground water. Drainage canals in coastal areas have allowed sea water to migrate inland where it seeps into adjacent aquifers and in some coastal areas, such as southwestern Florida, canals have done far more to induce salt-water encroachment than pumping of wells.

Unconsolidated Deposits

Large quantities of water are stored and pumped from unconsolidated aquifers. This is largely due to their high permeability, widespread occurrence, and the relative ease of constructing wells in them. Many of these deposits occur near sources of induced recharge, such as lakes and rivers, resulting in relatively high sustained yields because surface water is induced into the ground. In addition, the water level in surficial unconsolidated deposits is commonly near land surface and pumpings lifts are short.

Many unconsolidated deposits lie along river valleys, forming the flood plain. They also originate as wind-blown deposits in coastal areas and in deserts. A third major type is formed by materials, generally coarse, that fill inter-mountain basins, such as those in parts of Arizona and southern California. These deposits may be hundreds of feet thick; recharge to them is derived largely from snowmelt and precipitation along surrounding mountains.

Much of the area lying north of the Missouri and Ohio Rivers, as well as other areas including New York and New England, are covered by Ice Age deposits. These consist of sand and gravel and glacial till -- a mixture ranging in grain size from clay to boulders that may include interbedded layers of sand or gravel. In many places glacial deposits now completely obscure the preglacial topography, hiding from view extensive sand and gravel-filled valleys -- major sources of ground water.

Unconsolidated deposits may receive great amounts of recharge directly from precipitation and, consequently, generally contain water of excellent quality. Because they are permeable, however, they may be readily polluted, particularly if they form the land's surface. Fortunately, most disease-causing organisms (pathogens) are filtered out of the water within a few tens of feet from the source and only the highly-soluble chemicals continue to move through them. Dissolved salt, for instance, is not filtered out of the water as it percolates through permeable earth materials.

AQUIFER CHARACTERISTICS

A. Fundamental Principles

In order to understand and appreciate the occurrence and movement of ground water it is necessary to describe a few fundamental principles that deal with the rock materials, the open spaces within these materials, and with the contained fluids.

Any rock in which the interconnected spaces are filled with water can serve as an aquifer (water-bearing stratum). Some rock materials are better reservoirs than others. This is largely due to the shape and size of the grains, the number of openings between them (porosity), their interconnection (permeability), and the thickness of the deposit.

In order to properly manage a ground water reservoir, both technically and legally, it is necessary to have an understanding of the various properties of aquifers and how the water in an aquifer reacts to various stresses.

The Water Table

Earth materials below the land surface can be divided, for hydrologic purposes, into two zones: the upper zone of aeration and the underlying zone of saturation. The zone of aeration contains a soil-water belt, an intermediate belt, and the deeper capillary fringe (Figure 4). These belts range widely in thickness, depending on topography, soil type, and climate.

The zone of saturation, which may be several miles in thickness, is characterized by all of the pores being filled with fluid, generally

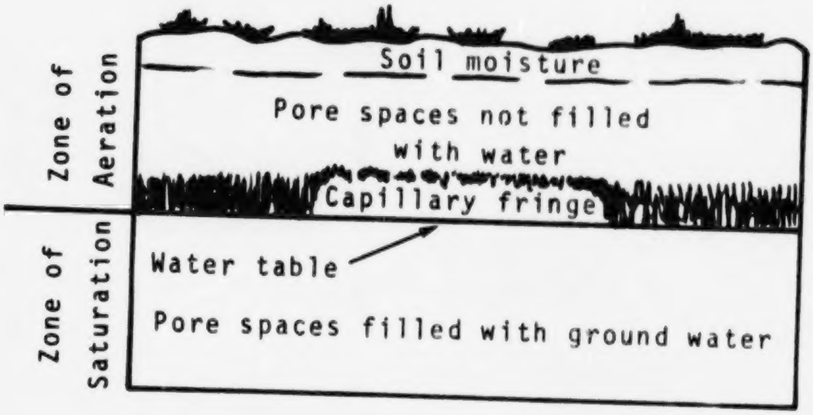

Zone of Aeration
Soil moisture
Pore spaces not filled with water
Capillary fringe
Zone of Saturation
Water table
Pore spaces filled with ground water

Figure 4. Ground water is the part of subsurface water within the zone of saturation.

water. Water in the zone of saturation is called "ground water". The boundary separating the zones of aeration and saturation is the water table, the position of which can be determined by noting the elevation of the water level in shallow wells.

The position of the water table can also be determined by noting the altitude of springs, seeps, marshes, lakes, water in excavations, and streams, all of which are merely points where the water table intersects land surface. The water table tends to follow the contours of the land surface, but the depth is generally greater beneath hills than it is beneath adjacent valleys (Figure 5).

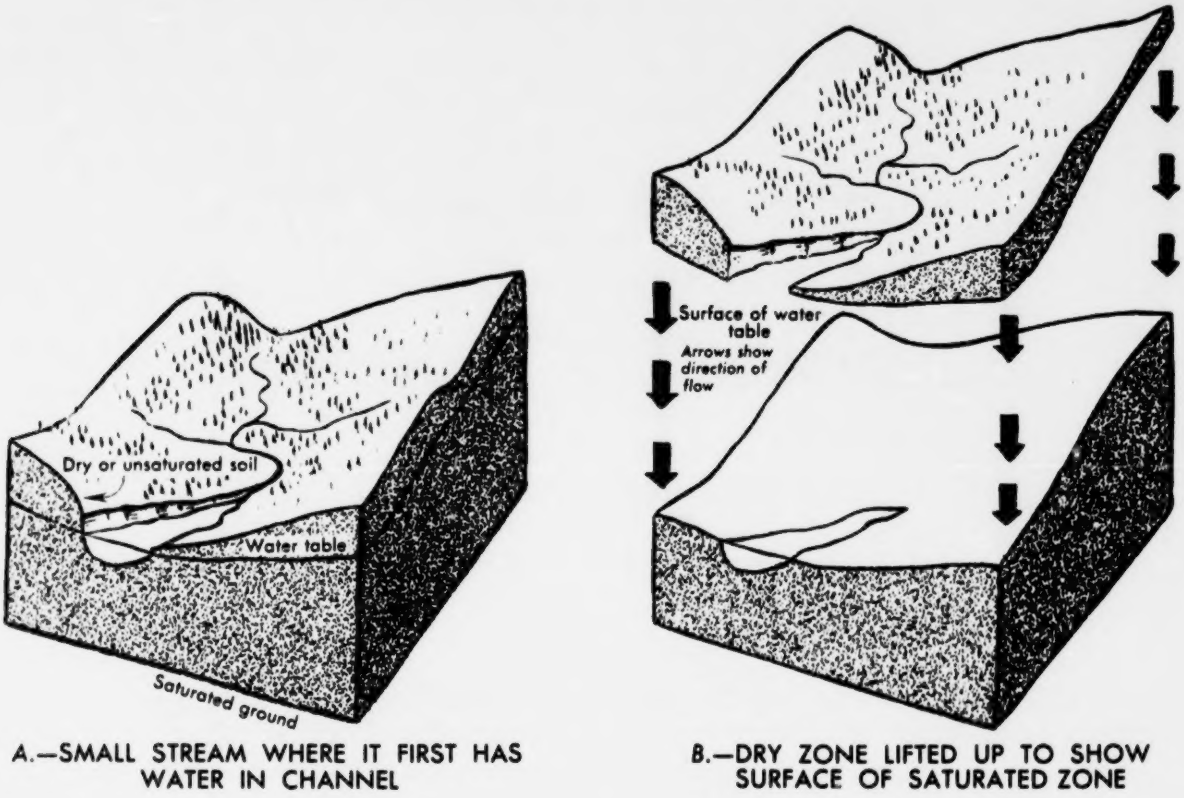

Dry or unsaturated soil
Water table
Saturated ground
A.—SMALL STREAM WHERE IT FIRST HAS WATER IN CHANNEL
Surface of water table
Arrows show direction of flow
B.—DRY ZONE LIFTED UP TO SHOW SURFACE OF SATURATED ZONE

Figure 5. Relation of ground surface to water table. A stream channel or rill has water flowing in it where the channel bottom is at a lower elevation than the water table. (U.S.G.S.)

Types of Aquifers

Three major types of ground water reservoirs (aquifers) are commonly recognized by hydrologists: unconfined, confined, and leaky. Their recognition is important from technical, managerial, and legal points of view since, hydrologically, they react in considerably different manners. An unconfined or water-table aquifer has a free water surface (water table) exposed to the soil atmosphere (Figures 4 and 5). Water is released from an unconfined aquifer by gravity drainage.

A confined or artesian aquifer is enclosed by layers of such low permeability that the water, confined to the more permeable inter-

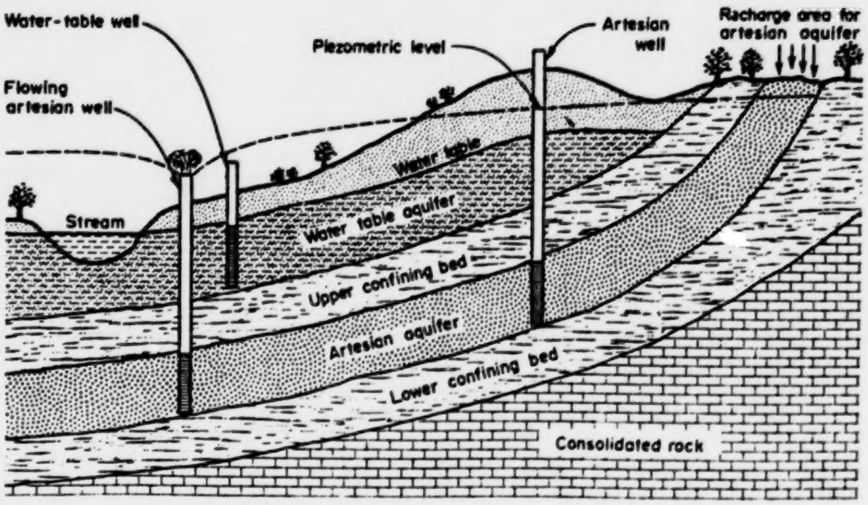

Water-table well
Flowing artesian well
Piezometric level
Artesian well
Recharge area for artesian aquifer
Water table
Stream
Water table aquifer
Upper confining bed
Artesian aquifer
Lower confining bed
Consolidated rock

Figure 6. Subsurface and ground water phase of the hydrologic cycle. (From Johnson, 1966, p. 17)

vening strata, is under hydrostatic pressure in a manner similar to water in a tilted pipe (Figure 6). Withdrawal of water from a confined aquifer may result in a pressure decrease over a wide area, exemplified by widespread lowering of the water-pressure (piezometric or potentiometric) surface.

A leaky artesian aquifer is closely related to a confined aquifer except that water under higher hydrostatic head (pressure) may slowly migrate into it through the confining beds, particularly during periods of pumping. In the leaky case, pumping causes a decline of the water-pressure surface, but generally it is of less magnitude than in a confined aquifer.

A special case is a perched aquifer, which lies above the principal aquifer or regional water table (Figure 7). The areal extent of

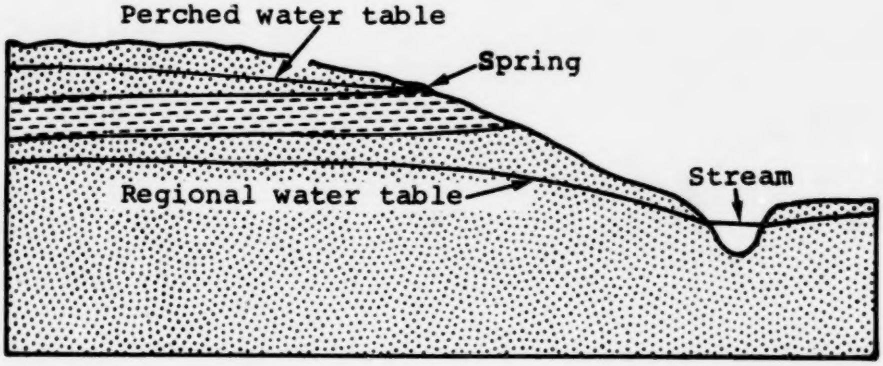


Figure 7. Perched water table occurs above impervious stratum and above the main water table.

perched aquifers ranges within wide limits and, although generally small, they may provide the principal source of water in a large number of local areas.

B. Water in Rocks

Recharge

The major source of ground water is precipitation that infiltrates aquifers (recharge). Recharge rates vary throughout the year because they are dependent on vegetation, soil moisture, evaporation and transpiration, frequency and rate of precipitation, and freezing of the surface. Several techniques have been devised to measure annual regional recharge rates, but rates differ considerably from place to place as well as from time to time and, consequently, the amount of recharge measured in local areas could be much greater or smaller than the regional rate.

In many areas it has been possible to increase recharge by artificial means, thus providing larger quantities of ground water locally and higher water levels. Some well fields (Figure 8) are constructed along watercourses and pumping tends to induce water to flow from the river into the adjacent streamside aquifer (induced infiltration). If the rate of recharge to any aquifer system is greater than the total outflow (discharge), water levels will rise; if less, they will decline; and a relatively constant annual water level indicates a balance between recharge and discharge.

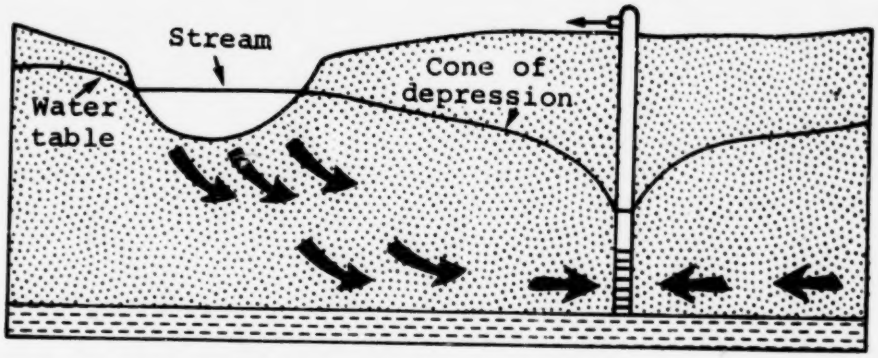


Figure 8. Cone of depression expanding beneath river bed creates a hydraulic gradient between the aquifer and river. This can result in induced recharge to the aquifer from the river.

Gradient

The difference between water levels in two wells tapping the same aquifer is the hydraulic gradient (Figure 9). Ground water flows down-gradient following the path of least resistance. A water-level map, prepared by drawing lines of equal water-level elevation on a base map, shows the regional gradient (Figure 10). From these maps

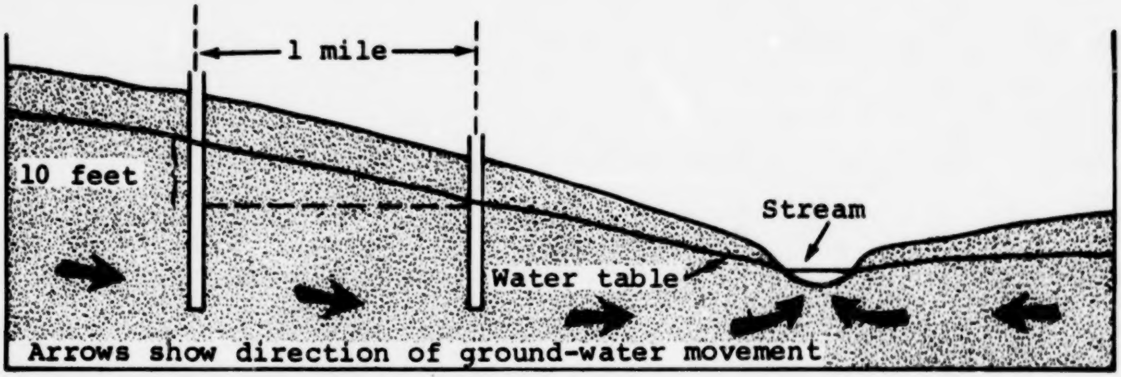

1 mile
10 feet
Stream
Water table
Arrows show direction of ground-water movement

Figure 9. The water level gradient is the difference in water level between two measuring points. In this case the difference in water level between two wells a mile apart is 10 feet: gradient is 10ft/mile.

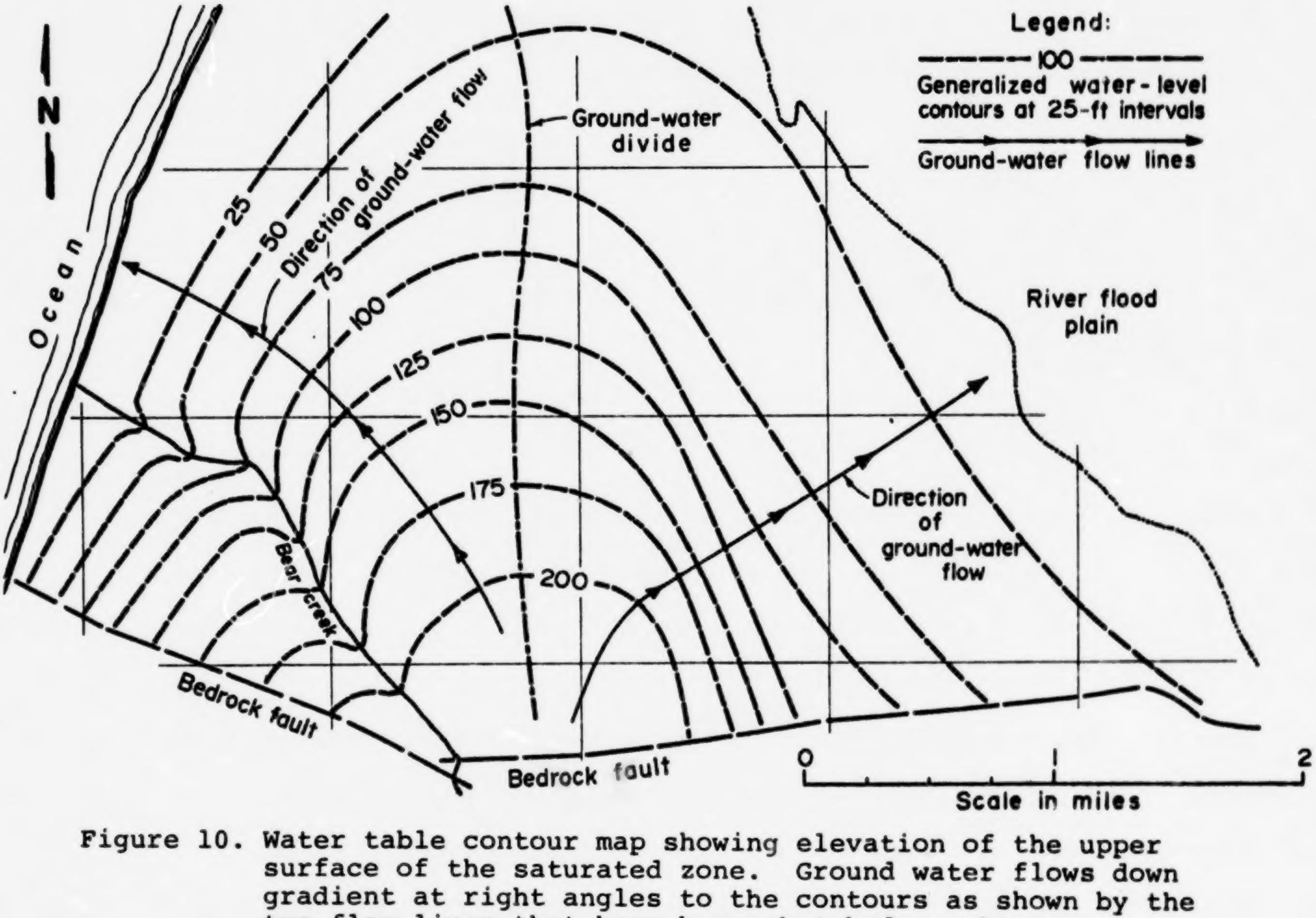

N
Legend:
100
Generalized water-level contours at 25-ft intervals
Ground-water flow lines
Ground-water divide
Direction of ground-water flow
Ocean
25
50
75
100
125
150
175
200
River flood plain
Direction of ground-water flow
Bear Creek
Bedrock fault
Bedrock fault
0
1
2
Scale in miles

Figure 10. Water table contour map showing elevation of the upper surface of the saturated zone. Ground water flows down gradient at right angles to the contours as shown by the two flow lines that have been sketched on the map. (Modified from Johnson, 1966, p. 40).

one can determine, among other things, the direction of ground water movement and places of recharge and discharge.

Artesian ground water is confined under hydrostatic pressure between layers of low permeability. In such a case, the aquifer is full and if a well is drilled into it, the water will rise to some position above the base of the overlying confining bed. The imaginary surface to which this water would rise in an infinite number of wells is called the artesian, water-pressure, piezometric, or potentiometric surface. It can be represented on a map. If a well is drilled into an artesian aquifer in an area where the potentiometric surface is at a higher altitude than land surface, the well will flow.

Water-level Fluctuations

Generally ground water levels fluctuate throughout the year in reponse to changes in the aquifer system, such as seasonal changes in recharge rates. These may change the levels several feet per year. Fluctuations also occur due to pumping (Figure 11). Because pumping from an artesian system does not dewater the aquifer but instead lowers pressures, changes take place with great rapidity. In water-table aquifers, pumping dewaters the pores, thus water-level changes are much slower. If the rate of pumping exceeds the overall rate of recharge, the water level will continue to decline. Monitoring of ground water levels is necessary to obtain hydrologic data and to evaluate aquifer performance information that can be used to develop aquifer-management techniques.

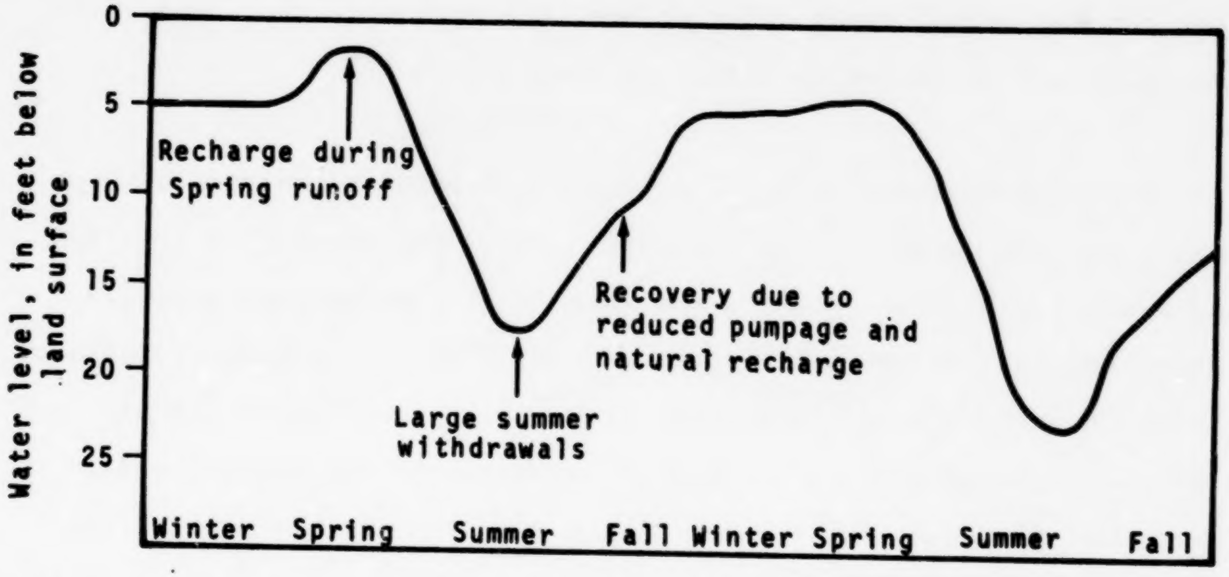


Figure 11. Ground water level fluctuations occur in response to natural and man-made influence.

C. Ground Water Movement

Velocity and Quantity of Flow

Under natural conditions, ground water generally moves at very slow rates, ranging from a fraction of an inch per year to many feet per day. The rate of movement is largely dependent on the aquifer permeability, water-level gradient, and effective porosity. A pumping well will increase the ground water gradient in the vicinity of the discharging well and thus will cause larger volumes of water to move through the area. Since ground water moves at such relatively slow rates, parts of an aquifer once polluted may remain unusuable for many years.

Effects of Pumping

The non-pumping water level measured in a well is called the "static level" (Figures 12 and 13). When pumping begins, the water surface in the well rapidly declines. The amount of decline is termed "drawdown"; the water level in the well is called the "pumping level". The water level declines not only in the well bore but also in surrounding areas, forming a cone of depression (Figures 12 and 13). The steep water-level gradient in the cone near the well is caused by removing water from the well and the surrounding deposits. The cone of depression spreads outward and deepens until a state of equilibrium between inflowing ground water and outflowing well water is reached. The cone of depression in an unconfined aquifer reflects the volume of rocks dewatered; its radius of significance is slow to develop and is generally less than a few hundred feet in diameter. In the confined aquifer, the cone represents a decline in pressure and develops very rapidly; it may have a significant radius of several miles.

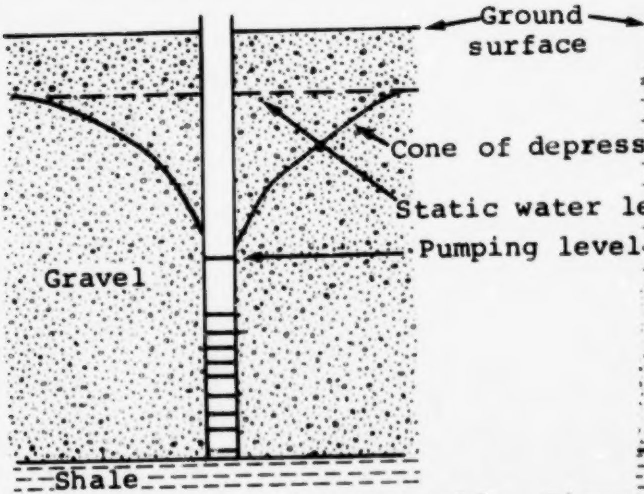


Figure 12. Diagram of water table well and cone of depression.

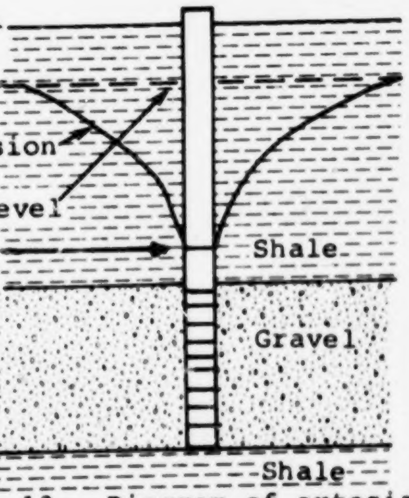


Figure 13. Diagram of artesian well and cone of depression.

1) Ground Water Management

Sustained Yield

The sustained yield of an aquifer system is that quantity of water that can be withdrawn from it without creating a significantly undesirable result. Parker (Parker and others, 1964) has called it the "water crop". It is the acceptable long-term balance between natural and man-made recharge and discharge. The sustained yield cannot be determined accurately prior to or even in the early stages of development, because the natural recharge rate is not known. It depends on the interactions of the aquifer framework, the hydraulics of the system, and methods of extraction, as well as social, legal, and managerial concepts. Only after the sustained yield is determined is it possible to optimize management of an aquifer system. The fact that it might require years to determine the sustained yield of an aquifer adds logic to the concept of issuing water rights that are valid for only a limited time. Studies have indicated that with a sufficient amount of data and a computer, a model can be constructed to simulate and predict drawdown and discharge of an area, thus providing insight into the sustained yield even in the early stages of ground water development.

Overdraft

Pumping which over a long period exceeds the recharge or defined sustained yield of an aquifer can lead to substantial water-level decline and dewatering of the system, possibly with unwanted results such as drying up of streams, lakes, shallow wells, and springs. When this occurs, wells can no longer produce at their design capacity and operation and maintenance costs increase. In addition, the lower water level may lead to interaquifer leakage of highly mineralized water or, in coastal areas, encroachment of sea water into fresh-water supplies.

In several parts of the world, the withdrawal of fluids such as water and petroleum has caused compaction of buried strata as the fluid pressures decrease. Such compaction leads to subsidence of the land surface, which may amount to several tens of feet. In turn, the subsidence may break underground pipelines and cause buildings to sink or be slowly torn apart. Areas suffering from extensive subsidence due to ground water pumping include, among many others, Mexico City and several areas in Arizona, California, and Texas, particularly in California's San Joaquin Valley.

Aquifer Interactions

As the cone of depression around a pumping well spreads outward, the entire area under its influence begins to interact in response to changes in the water level. Water levels will decline in shallower and deeper hydrologically-connected rocks because of the removal of water, interaquifer leakage, and change in volume of the surrounding rocks. Water will leak from adjacent deposits into strata with lower hydrostatic heads.

The cone of influence may intercept a stream, causing some reduction in its flow. The streamflow reduction occurs because ground water, which under natural conditions was flowing into the stream, is diverted toward the pumping well. If the ground water level becomes lower than the water level in the stream, the surface water may infiltrate and flow toward the well. In fact, pumping of ground water adjacent to a stream may cause not only a reduction in streamflow, it may actually cause the stream channel to become dry. In cases such as these, a pumping well is merely recapturing water from the stream that previously was naturally released from the ground. Furthermore, the water-level decline in the cone of depression around shallow water-table wells tends to decrease water losses from evaporation and transpiration and makes more underground storage space available.

Well Interference

The cone of depression surrounding a pumping well may extend outward for a considerable distance, causing wide-spread water-level lowering. Consequently, the water level in another well in the area of influence will decline even though it is not pumping; a well tapping the upper part of the aquifer system may go dry (Figure 14). When two nearby wells are pumping, the cones of depression will overlap and the net effect will be even more drawdown in each well (Figure 15). This composite water-level lowering effect is called "well interference". If the aquifer properties are the same at each well, but one is pumping at a rate several times greater than the other, there may be so much water-level decline in the second well that it can no longer produce at its design capacity. This condition affects not only individual

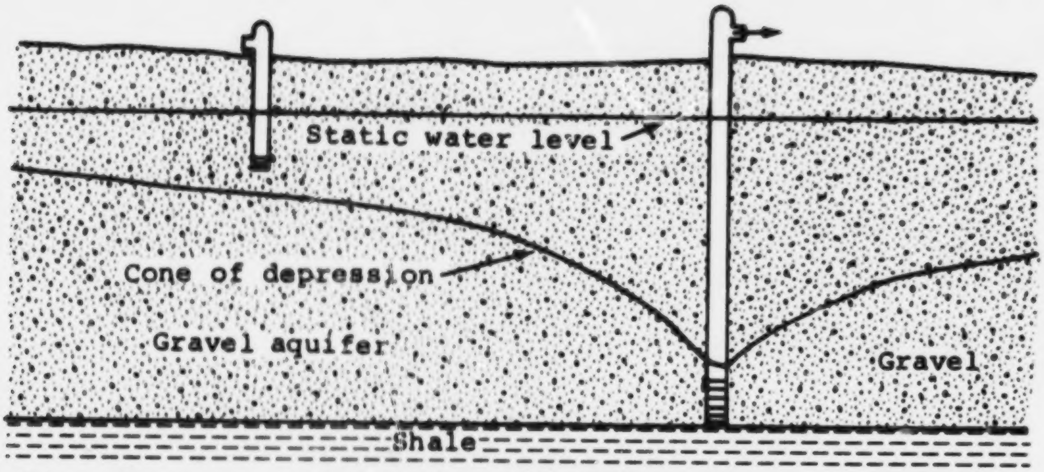

Static water level
Cone of depression
Gravel aquifer
Gravel
Shale

Figure 14. The cone of depression surrounding a pumping well may decline so much that nearby wells become dry.

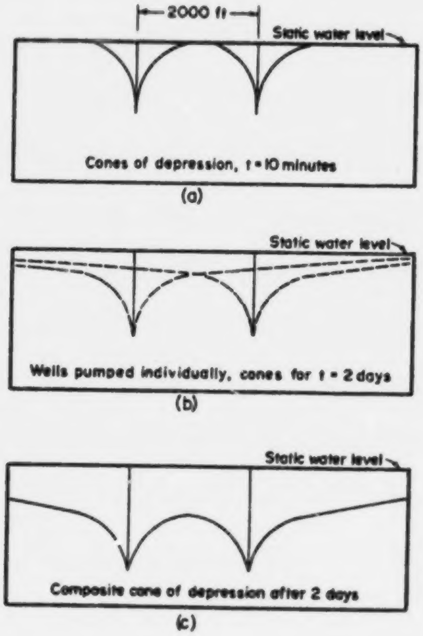

2000 ft
Static water level
Cones of depression, t = 10 minutes
(a)
Static water level
Wells pumped individually, cones for t = 2 days
(b)
Static water level
Composite cone of depression after 2 days
(c)

Figure 15. Development of interference between adjacent wells tapping the same artesian aquifer. Composite cone is for both wells pumping simultaneously under the assumed conditions.
(Modified from Johnson, 1966, p. 128)

wells but may reduce the efficiency of entire well fields that are too densely spaced. Well interference of this type caused a "water war" to develop in the Upper Tampa Bay Area, Florida (Parker, 1975). More commonly, such situations occur where the aquifer is of variable thickness or the wells are of considerably different depths, resulting in adverse effects on the water level in a shallow well or one tapping a thin part of the aquifer.

Well Efficiency

Owing to ignorance or cost considerations, many wells are not adequately designed and therefore are inefficient. Domestic wells, for example, which commonly deliver only a few gallons a minute, may be poorly constructed and generally only partially penetrate the aquifer. High-yield wells usually are larger and deeper and are better designed and constructed. A poorly-designed domestic well may have more drawdown within the well than a nearby high-yield well even though the pumping rate of the latter is 100 times greater. Thus, loss of water in a given case may be the result of poor well design, where a properly designed well would not have been significantly affected by a lowering of the water level.

GROUND WATER REGIONS*

The United States exclusive of Alaska and Hawaii has been divided into ten ground water regions (Figure 16). These regions are widely recognized as the best broad classification of the ground water situation of the coterminous states. The division is based principally on types of aquifers. Most of the major rivers drain one or more of the regions.

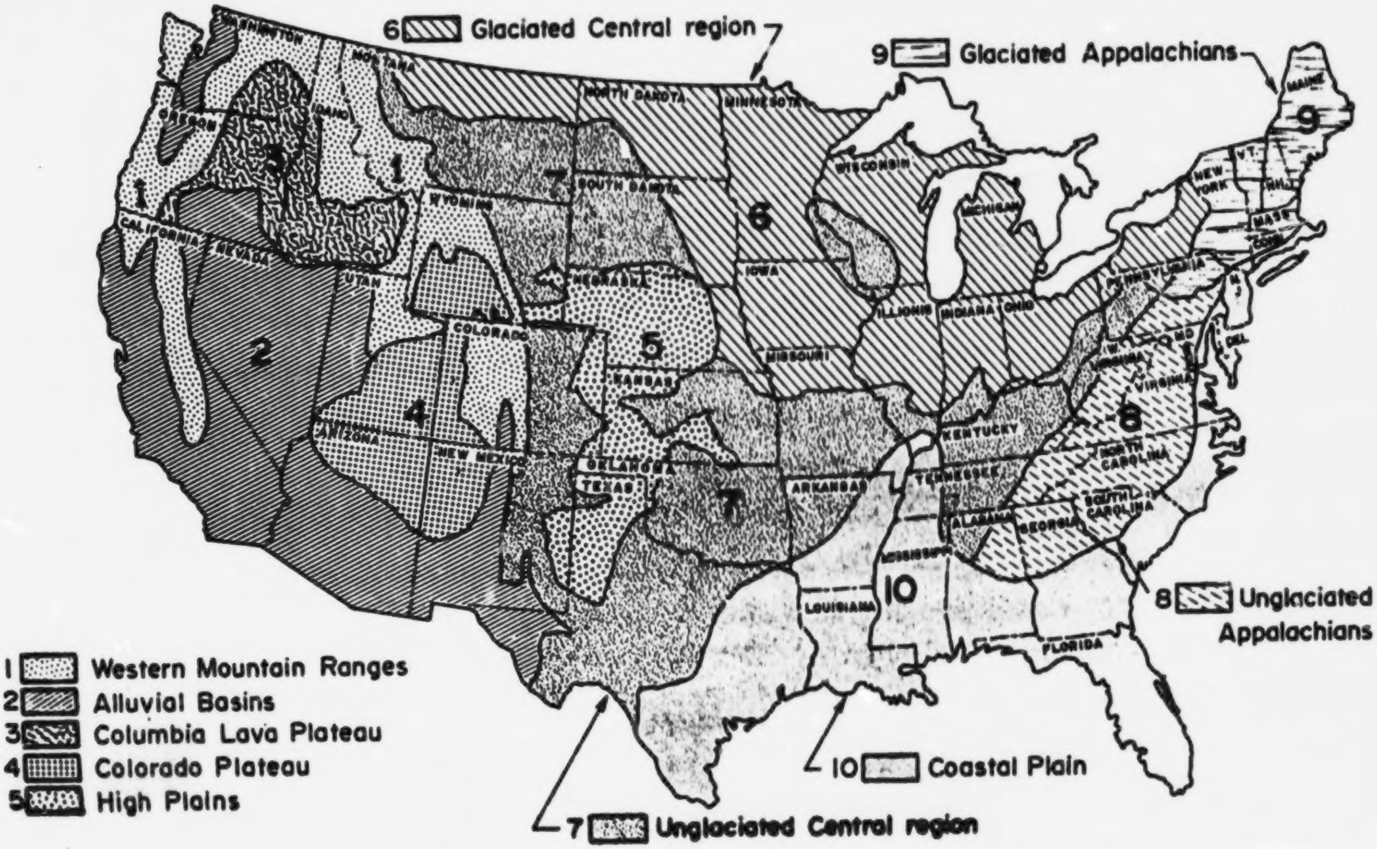

6 Glaciated Central region
9 Glaciated Appalachians
8 Unglaciated Appalachians
10 Coastal Plain
7 Unglaciated Central region
1 Western Mountain Ranges
2 Alluvial Basins
3 Columbia Lava Plateau
4 Colorado Plateau
5 High Plains
WASHINGTON
OREGON
CALIFORNIA
NEVADA
IDAHO
MONTANA
WYOMING
UTAH
COLORADO
ARIZONA
NEW MEXICO
NORTH DAKOTA
SOUTH DAKOTA
NEBRASKA
KANSAS
OKLAHOMA
TEXAS
MINNESOTA
IOWA
MISSOURI
ARKANSAS
LOUISIANA
WISCONSIN
ILLINOIS
INDIANA
OHIO
MICHIGAN
KENTUCKY
TENNESSEE
MISSISSIPPI
ALABAMA
GEORGIA
FLORIDA
SOUTH CAROLINA
NORTH CAROLINA
VIRGINIA
W. VIRGINIA
PENNSYLVANIA
NEW YORK
MAINE
VT.
N.H.
MASS.
CONN.
N.J.
DEL.
MD.
1
1
1
2
3
4
5
6
7
7
7
8
9
10

Figure 16. Ten major ground water regions of the United States, excepting Alaska and Hawaii. (After Thomas and McGuinness)
(From Johnson, 1966, p. 48)

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*Material from this section is largely from Johnson, 1966, pp. 47-60.

1. Western Mountain Ranges

The Western Mountain Ranges Region includes the Rocky Mountains, Cascade Range, Sierra Nevada, the northern Coastal Ranges, and a few other isolated mountains in the same general area (Figure 16). The major rocks in this region consist principally of igneous, metamorphic, and consolidated sedimentary rocks. These rocks are generally unfavorable for the occurrence of ground water. Consequently, aquifers in this region are of limited areal extent, generally small in volume, and provide relatively small yields. Most of the ground water occurs in fractures in the rocks. A few unconsolidated deposits, which yield larger amounts of water, occur along streams and in a few small valleys. The mountain ranges receive a large amount of precipitation but most of it is released and the runoff recharges aquifers in adjacent regions. Because the annual precipitation rate is high and the population sparse, ground water demands, for the most part, are small.

2. Alluvial Basins

The Alluvial Basins Region consists of valleys surrounded by mountain ranges (Figure 16). The valleys represent large basins that are nearly filled with unconsolidated material, such as silt, clay, sand, gravel, and boulders, eroded from the adjacent mountainsides. With the exception of the trough between the Coast Ranges and the Cascade Range, this region typically is arid. Although precipitation ranges from three to more than 60 inches per year, most of the region receives less than 15 inches annually. Much of the precipitation is poorly distributed throughout the year and, unfortunately, inadequate during the growing season. Throughout this region, huge quantities of ground water are used, particularly for irrigation. The water is drawn from valley-fill deposits that are generally a few hundred feet thick but in some places are as much as several thousand feet thick. At the turn of the century, it was assumed that the ground water stored in the Alluvial Basins was inexhaustible. However, water levels in many places have declined excessively due to nearly 70 years of pumping*, and the quantity of water in storage has been significantly reduced. Great volumes of water remain stored in some valleys that are, as yet, untapped. The annual recharge to these underground reservoirs is small; it consists primarily of seepage from streams that originate along the mountain fronts. As pointed out by H. E. Thomas:

> "The principal residential, agricultural, and industrial sites of the southwest are included in this region. There is an enormous water demand with potential demand even greater because of rapid population growth and the existence of fertile land waiting to be irrigated. Available surface water is appropriated and, in some cases, over-appropriated."

In view of the exceptionally large withdrawal of ground water, water levels have declined significantly. This, in turn, has permitted the intrusion of sea water into coastal aquifers and allowed salty deeper water to migrate into the fresh inland water zones. Furthermore, repeated reuse has caused deterioration of the quality of both surface water and ground water. In other areas the lands are characterized by poor drainage, and irrigation has led to water-logging.

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*Heavy pumping for irrigation in the San Joaquin Basin began about 1905. It increased dramatically following the end of World War II.

3. Columbia Lava Plateau

This region lies principally in eastern Washington, eastern Oregon and adjacent parts of Idaho (Figure 16). It is underlain mainly by lava flows, although a few basins are filled with hundreds of feet of unconsolidated sediments, chiefly glacial-outwash detrital materials (sand and gravel). The region is characterized by volcanic materials that range from less than 100 to several thousand feet in thickness. Water-bearing units occur in lava flows characterized by open fractures and, in places, in permeable zones between successive lava flows. In a few areas such as at Spokane, Washington, very permeable layers of outwash sand and gravel provide extremely large yields to wells. Along the Snake and Columbia Rivers, large quantities of surface waters are used for irrigation and hydroelectric power. Some irrigated areas have become waterlogged.

4. Colorado Plateau

This region consists of high, dry plateaus lying in adjacent parts of Wyoming, Colorado, Utah, Arizona, and New Mexico (Figure 16). Here the rocks consist largely of sedimentary strata, many of which are broken into large blocks by faults. Most of the rocks consist of shale and sandstone. This semiarid to arid region is sparsely populated; the scarcity of productive aquifers will also limit future development. Most of the major water-bearing zones consist of sandstone, although water does occur in limestone and unconsolidated sediments in a few places. Generally, existing wells yield only a few gallons per minute.

5. High Plains

The High Plains include an extensive semiarid to sub-humid region lying east of the Rockies, extending from South Dakota to western Texas and eastern New Mexico. The extensive surficial deposits consist largely of sand and gravel; the water that is drained from them is replenished primarily by rain and snow. Most of the unconsolidated deposits comprise the Ogallala Formation, which in places is more than 500 feet thick. It is the principal aquifer over several thousand square miles. The materials forming the Ogallala Formation range widely from very fine to coarse, with abrupt variations in grain size within short distances, both vertically and horizontally. Locally, stream deposits constitute important aquifers along the larger stream channels. Wells yield moderate to large quantities of water, but the natural recharge rate ranges widely, being generally least in the southern part and greatest in the north. Pumping of wells in the river valley alluvium tends to deplete the stream flow, resulting in usurpation of long-established downstream water rights. This has resulted in court suits and in state water laws prohibiting the depletion of stream flow by such wells.

An extensive deposit of windblown sand and loess lies on the Ogallala Formation between the Platte and Niobrara Rivers. These windblown deposits form the well-known sandhills of Nebraska. Here precipitation readily infiltrates and natural recharge is estimated to be about five inches of water per year. Southward, in the High Plains of Texas, the recharge rates are considerably less, ranging from an inch to considerably less than an inch per year. Highly productive wells have led to extensive irrigation. In Texas, more than 50,000 irrigation wells are in use; in Nebraska, there are more than 40,000, most of them drilled within the past 30 years. In some heavily pumped parts of the region withdrawals have far exceeded the natural recharge rate and, consequently, the total quantity of water in storage is being significantly reduced. Reduction of well yields has occurred in some areas. Management schemes including ground-water mining, integrated surface-water and ground-water use, artificial recharge, and regulations are being employed or considered.

6. Glaciated Central Lowland

This huge ground water region, extending from Montana on the west to New York on the east, is largely bounded in the United States by the Missouri and Ohio Rivers, which generally mark the limits of glaciation. Much of this region is covered with extensive deposits of glacial drift, which in some areas contains highly permeable deposits of sand and gravel. Lying on or bordering the drift are important water-course aquifers consisting of sand and gravel. These are exemplified by deposits along the Ohio, Missouri, and Mississippi Rivers, as well as their major tributaries. Directly underlying the drift are extensive buried river deposits, which, although generally hidden from view, provide large quantities of water to wells. Consolidated deposits underlying the drift also serve as major ground-water reservoirs, such as the extensive sandstone aquifers that underlie large parts of Iowa, Minnesota, Wisconsin, Illinois, and Michigan. Elsewhere under the drift are permeable carbonate rocks. Although local shortages do exist throughout most of this vast region, adequate quantities of ground water are widely available. In some of the heavily populated and highly industrialized areas, many ground water supplies have been overdeveloped or polluted, or both.

7. Unglaciated Central Region

This vast region consists of interior plains extending southward from Montana to Texas and eastward to Pennsylvania (Figure 16). It also includes a small unglaciated area that lies largely in southwestern Wisconsin. Most of the rocks in this region are horizontal, or only gently dipping, consolidated sedimentary rocks. Limestone and sandstone provide the major aquifers; yields are only low to moderate. Highly permeable aquifers, however, occur as unconsolidated deposits along the larger streams. Throughout this region, the adequacy of water supplies is closely related to rainfall, which decreases considerably from east to west. In general, ground water is adequate for domestic supply but inadequate for irrigation and other large uses. Most large-scale ground water developments depend upon induced infiltration along the major streams.

8. Unglaciated Appalachians

This region, extending from the border of the Coastal Plain in Alabama and Georgia northeastward to Pennsylvania and New Jersey, is characterized by mountains and rolling hills separated by linear valleys. In the western part, extensive elongate deposits of limestone provide large quantities of water to springs and wells. The Appalachian Plateaus form the western-most part of the Unglaciated Appalachians. Here the underlying bedrock consists chiefly of limestone, sandstone, and shale of which only limestone and sandstone may provide fairly high yields to wells. Because valleys are cut deeply into the plateaus, the water level may lie at considerable depths. This region is humid; it includes areas of the heaviest annual precipitation in the eastern part of the United States, where streamflow is rather uniform throughout the year. Consolidated aquifers in this region generally are sufficient for domestic purposes, but, except for limestone areas, inadequate for large water requirements. Large quantities of ground water can be produced, however, from sand and gravel deposits along the major streams and rivers.

9. Glaciated Appalachians

Extending northeastward from eastern Pennsylvania and including all of the New England states, is the Glaciated Appalachians ground water region. The rocks and water-yielding characteristics are similar to the Unglaciated Appalachians to the south. Sandstone and carbonate strata as well as igneous and metamorphic rocks provide the major bedrock yields, but less than ten per cent of the region is underlain by productive bedrock aquifers. Throughout much of the region glacial till mantles most of the surface. The most productive aquifers are sand and gravel deposits that form outwash plains and fill valleys, but many of these are of limited thickness. Valley-fill deposits occur both in existing streams and as buried-valley deposits. In view of the heavily populated and industrialized nature of this region, many surface-water sources are polluted, which in turn may lead to pollution of streamside aquifers.

10. Atlantic and Gulf Coastal Plain

This coastal region, extending from Massachusetts to Texas, includes a sequence of rocks that dip gently seaward. There is an abundance of both surface water and ground water. Many of the aquifers consist of unconsolidated deposits of gravel, sand, silt, and clay. Elsewhere, particularly in Florida and to a lesser extent in Alabama and Georgia, aquifers consist of extensive deposits of highly permeable limestone. The sediments forming the coastal plain range in thickness from nearly zero to more than seven miles. Fresh-water aquifers in some areas lie at depths in excess of 6,000 feet. The major aquifers outside of Florida consist of sand and gravel. Consolidated rock aquifers, however, include highly productive carbonates in Florida, southeastern Georgia, and South Carolina. Supplies are not abundant in a few localities in Texas, Louisiana, Mississippi, and Alabama. In Florida, with extensions into Alabama and Georgia, is one of the world's most prolifically yielding ground water reservoirs, the great Floridan Aquifer. Along the southeastern Florida coast is the wedge-shaped Biscayne Aquifer, a water-table aquifer which, in its capacity to produce well water, ranks with clean, well-washed, well-graded gravel deposits.

WATER QUALITY

GENERAL CONSIDERATIONS

As water moves through the hydrologic cycle, its quality changes in response to differences in the physical and chemical environments through which it passes (Figure 17). The changes may be either natural or man-influenced; in some cases they can be controlled, in others they cannot, but in most they can be managed in order to limit adverse water-quality changes.

Water Quality Characteristics Due To Natural Causes

The physical, chemical, and biological quality of water may range within wide limits even though there are no man-made influences. In fact, it is often impossible or at least difficult to distinguish the origin (man-made or natural) of many water-quality problems. The natural quality reflects the types and amounts of soluble and insoluble substances with which the water comes in contact. Surface water generally contains less dissolved solids than ground water, although in areas where ground water is the major source of streamflow the quality of both types is similar except during times of floods, when surface water in the stream dominates the ground water contribution. During

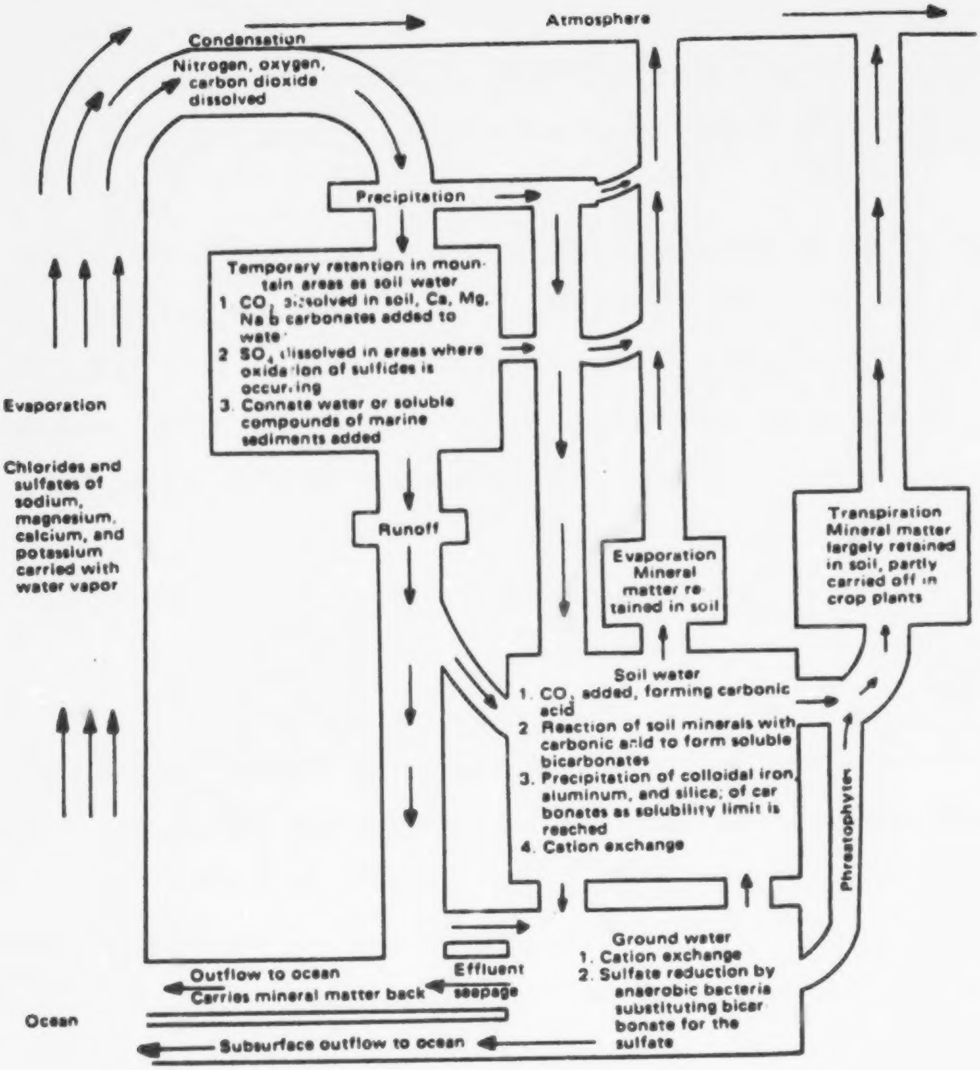

Condensation
Atmosphere
Nitrogen, oxygen, carbon dioxide dissolved
Precipitation
Temporary retention in mountain areas as soil water
1 CO_2 dissolved in soil, Ca, Mg, Na b carbonates added to water
2 SO_4 dissolved in areas where oxidation of sulfides is occurring
3. Connate water or soluble compounds of marine sediments added
Evaporation
Chlorides and sulfates of sodium, magnesium, calcium, and potassium carried with water vapor
Runoff
Evaporation Mineral matter retained in soil
Transpiration Mineral matter largely retained in soil, partly carried off in crop plants
Soil water
1. CO_2 added, forming carbonic acid
2 Reaction of soil minerals with carbonic acid to form soluble bicarbonates
3. Precipitation of colloidal iron, aluminum, and silica; of carbonates as solubility limit is reached
4. Cation exchange
Phreatophytes
Ground water
1. Cation exchange
2. Sulfate reduction by anaerobic bacteria substituting bicarbonate for the sulfate
Effluent seepage
Outflow to ocean
Carries mineral matter back
Ocean
Subsurface outflow to ocean

Figure 17. Geochemical Cycle of Surface and Ground Water
(Source: U.S.G.S.)
(From Todd, 1970)

periods of surface runoff, streams may contain large quantities of suspended materials and, under some circumstances, a large amount of dissolved solids. Most commonly, however, during high rates of flow the water has a lower dissolved-mineral concentration.

Ground water is characterized by nearly constant chemical and physical properties, at least on a local scale. As a general rule, the dissolved-solids content increases with depth, and with the time and distance the water has traveled in the ground. A few uncommon water-quality situations exist throughout the country, reflecting unusual geologic and hydrologic conditions. These include, among others, thermal areas and regions characterized by high concentrations of certain elements, some of which may be health hazards.

Examples of anomalous water-quality areas include several playa lakes and springs in Texas and Arizona. Playas are intermittent lakes which occur throughout much of the arid-lands region west of the Mississippi River. Near Willcox, Arizona, salts have become highly concentrated in ground water under playas, due to evaporation. This has led to extremely high concentrations of fluoride in the water, which if consumed over a period of time can be toxic. Many springs in west Texas and central Arizona are fed by ground water that has migrated through evaporate (salt) deposits. Consequently, the springs and many water courses are salty.

Water Quality Influenced By Man's Activities

For centuries man has been disposing of his waste products by placing them in streams, storing them on the ground, or by various methods putting them in the ground. Man-made influences on stream-water quality reflect not only waste discharge directly into the stream, but also include highly mineralized or polluted surface runoff, which can carry a wide variety of substances. Another major influence on surface-water quality is related to the discharge of ground water into the stream. If the adjacent ground water is polluted, stream quality tends to deteriorate. Fortunately in the latter case, the effect in the stream will not be as severe as it is in the ground, due to dilution and dispersion of the pollutant. In most cases, however, the general quality of ground water is such that it actually serves as a dilutant to man-caused surface-water pollution.

The quality of ground water, in addition to natural inputs, is most commonly affected by waste disposal. Another major source of pollution is the storage of waste materials in excavations, such as pits or mines. Water-soluble substances that are dumped, spilled, spread, or stored on the land surface or in excavations may eventually infiltrate to pollute ground water resources. Ground water is also polluted by the disposal of fluids through wells and, in limestone terrains, through sinkholes directly into aquifers. Likewise, infiltration of highly mineralized surface water has been a major cause of underground pollution in several places. Irrigation tends to increase the mineral content of both surface and ground water. The degree of severity of pollution in cases such as these is related to the hydrologic properties of the aquifers, the type and amount of waste, disposal techniques, and climate.

A major and widespread cause of ground-water quality deterioration is related to pumping, which may cause the migration to the well of more highly mineralized water from surrounding strata. The migration is directly related to differences in hydrostatic head (pressure) between adjacent water-bearing zones, and relative permeabilities. In coastal areas pumping may cause sea water to invade a fresh water aquifer. In parts of coastal west Florida, wild-flowing, abandoned artesian wells have salted large areas of formerly fresh or slightly brackish aquifers, ruining them.

Reclamation of Contaminated Aquifers

As pointed out previously, aquifers react in a manner similar to a sponge. Visualize, for example, a bath sponge that has been liberally injected with soap. Even though the soapy sponge is filled and the water squeezed out of it many times, soap bubbles continue to appear with each new flushing. It may require hours of flushing and squeezing to remove all the soap.

The situation is similar in polluted aquifers--once polluted, they may be exceedingly difficult or impossible to reclaim. The polluted water in the aquifer can be treated, perhaps even economically, but the earth materials forming the aquifer cannot be so treated.

Several natural processes tend to degrade or remove certain substances as polluted water flows through an aquifer. These natural renovation processes include dispersion and dilution, in addition to several geochemical reactions. Techniques to restore an aquifer include pumping the ground water to waste and diluting it by artificial recharge --methods that are expensive and commonly of questionable economic value. Obviously the most effective method of ground water quality control is protection from pollution.

CONTROL METHODS

Ground water quality can be maintained by the development and enforcement of surface water effluent standards; land-use regulations; stringent controls over all types of disposal sites, land spreading of fertilizers, pesticides and wastes, and storage of solid and liquid materials; and by careful management of water level and pumping rates in ground water systems, control of well construction and operation, air quality control, and control of activities such as mining. Statutes, rules, regulations, and guidelines must, however, be based on sound geologic and hydrologic data and interpretations.

Ground Water Quality Problems

Man-influenced ground water quality problems are most commonly related to: (1) water-soluble products that are placed on the land surface and in streams; (2) substances that are deposited or stored in the ground above the water table; and (3) disposal, storage, or extraction of material below the water table. Many of the pollution problems related to these situations are highly complex, and some are not well understood. Technical solutions to many ground water quality problems are straightforward and controls are easily implemented, at least insofar as techniques are concerned. Legal and social constraints, however, may prevent effective control.

A. Ground Water Quality Problems That Originate On the Land Surface

Many ground water quality problems are caused by the disposal of wastes directly into streams and by the dumping, spreading, or storage of soluble substances on the land surface. The following table, although not all-inclusive, lists the major causes of ground water pollution that originate on the land suface.

1. Infiltration of polluted surface water.
2. Land disposal of either solid or liquid waste materials.
3. Stockpiles.
4. Dumps.
5. Disposal of sewage and water-treatment plant sludge.
6. Salt spreading on roads, airport runways, and parking lots.
7. Animal feedlots.
8. Fertilizers and pesticides.
9. Accidental spills of hazardous materials, including atomic wastes.
10. Particulate matter from airborne sources.

Infiltration of Polluted Surface Water

The yield of many wells tapping streamside aquifers is sustained by infiltration of surface water. In fact, more than half of the well yield may be derived directly from induced recharge from the nearby stream, which may be polluted (Figure 18). As the induced water migrates through the ground, a few substances (although by no means all) are diluted or removed by filtration and sorption. This is particularly true where the water flows through filtering materials, such as sand and gravel. Filtration is less likely to occur if the water flows through large openings such as those that occur in carbonate aquifers. Many pollutants, as for example chloride, nitrate, and sulfate, are highly mobile, move freely with the water, and are not removed by filtration.

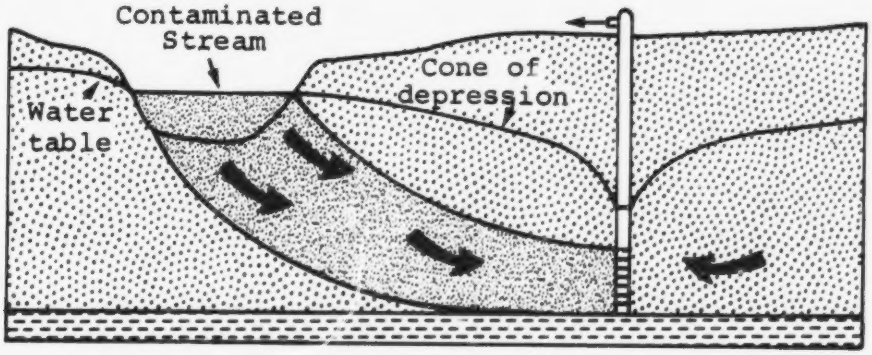


Figure 18. Induced infiltration of contaminated stream water may lead to ground water pollution.

Examples of ground water supplies being degraded by induced recharge of polluted surface water are both numerous and widespread. In the greatest number of cases, the pollution originates from the disposal of municipal or industrial waste directly into the stream, which may then infiltrate into adjacent aquifers. In hydrologic situations such as these, months or perhaps years may be required for the pollutant to advance from the stream to the well. Once at the well, however, the aquifer between the well and the stream may be completely polluted, requiring years to recover once the source has been eliminated. The only realistic method of reducing ground water pollution of this type is adequate surface water effluent standards, stringently enforced.

Land Disposal of Either Solid or Liquid Waste Materials

One of the major causes of ground water pollution is the disposal of waste materials directly onto the land surface. Examples include manure, sludges, garbage, industrial wastes, etc. The waste may occur as individual mounds or it may be spread out over the land. If the waste material contains soluble products, they will infiltrate and may lead to ground water pollution (Figure 19). Similar problems occur in the vicinity of various types of stockpiles.

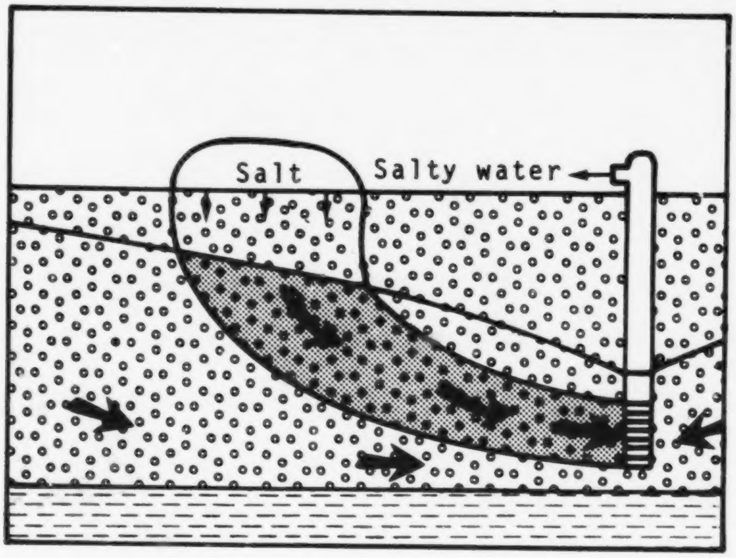


Figure 19. Leaching of solids at the land surface. The possibility of ground water pollution under these conditions is rarely anticipated.

Stockpiles

Perhaps the prime example of ground water pollution caused by stockpiles is related to salt used for highway snow and ice control. Not uncommonly, tons of salt are simply piled on the land surface awaiting use. The highly soluble material rapidly dissolves and either infiltrates or runs off into streams (Figure 19). In recent years, many highway officials have provided some protection for salt stockpiles by covering them with plastic sheets or storing the salt in sheds. This is not necessarily done for the protection of adjacent water resources, but merely to preserve the salt.

Dumps

Investigators recently have begun to take a serious look at the environmental effect of dumps. As rainwater infiltrates through trash in a dump, it accumulates a wide variety of chemical and biological substances. The resulting fluid, or leachate, may be highly mineralized and grossly polluted. As the leachate infiltrates, some of the substances it contains are removed or degraded. Eventually the leachate may reach the water table (in some places "sanitary fills" or dumps are below the water table), where it flows in the direction of the regional ground water gradient or toward a well (Figure 20). The potency and degree of mineralization of the leachate-polluted ground water is related to the size and age of the dump, the type of material in the dump and surrounding areas through which the leachate flows, the length of flow path before the water again appears at the surface, and the climate. Pollution of ground water by leachate from dumps can be reduced by regulation of the location, construction, and operation of solid-waste disposal sites.

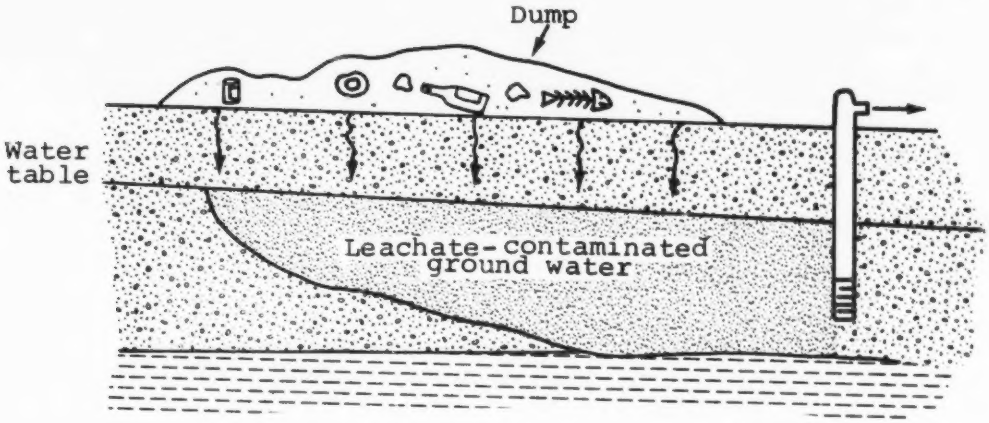


Figure 20. Ground water contamination caused by leachate infiltration from a dump.

Disposal of Sewage and Water Treatment Plant Sludge

The sludge from treatment plants presents not only a significant waste disposal problem but one that is growing, quantitatively, by leaps and bounds. The wastes include lime-rich sludge from water treatment plants as well as sewage sludge from waste water treatment plants. In recent years, municipal officials have attempted to solve the sewage-sludge problem by spreading the sludge on the land surface or filling strip mine pits with it. At first glance this may seem to be an effective means of disposal, but a wide variety of exotic chemicals, derived from domestic, agricultural, municipal, and industrial wastes may exist in the sludge as soluble or relatively insoluble substances. When the sludges are used as fertilizers, the soluble compounds may infiltrate while the more insoluble compounds, many of which may consist of toxic metals, are removed and concentrated by plants. Existing knowledge of the chemical and biological migration of numerous elements and compounds present in sludges is, at best, slight. A great deal of research is needed before land disposal of sewage treatment wastes should be permitted to become commonplace throughout the country.

Salt Spreading on Roads

In recent years, particularly since the construction of the interstate highway system, water pollution due to wintertime road salting has become an increasing problem. The effect is becoming even more severe as salt usage increases with a concomitant decrease in the use of sand. The salting brings about deterioration of stream quality due to highly mineralized surface runoff, and the infiltration of briney water causes ground water pollution. There appears to be a direct relationship between degree of pollution, rock type, and amount of salt used and storage techniques. Clearly, administrative controls are needed to protect ground water supplies in the vicinity of major highways and other heavily salted roads and near major points of salt handling, storage, and distribution.

Accidental Spills of Hazardous Materials

A wide variety of toxic materials are transported throughout the country by truck, rail, and aircraft; accidental spills of these hazardous materials are not uncommon. Presently, there are practically no controls on transportation of hazardous materials and virtually no methods that can be used to quickly and adequately clean up an accidental spill. Furthermore, immediately following an accident the usual procedure is to spray the spill area with water in order to wash the compounds from the road. The resulting fluid may then either flow into a stream or infiltrate into the ground. In a few cases, the fluids have been impounded by dikes, which lead to even greater infiltration. In any case, water resources may be easily and irreparably polluted from accidental spills of hazardous materials. Spills of atomic wastes constitute a special case because some are not only highly toxic, but have half-lives of thousands of years.

Fertilizers and Pesticides

An increasing amount of both fertilizers and pesticides are being used in the United States each year. Many of these substances are highly toxic. A wide variety, however, become quickly attached to fine-grained sediment, such as clay and silt particles, a part of which is removed by erosion and surface runoff. In many heavily fertilized areas, the infiltration of nitrate, a decomposition product of ammonia fertilizer, has grossly polluted ground water. The consumption of nitrate-rich water leads to a serious disease in infants commonly known as "blue babies" (methemoglobinemia).

Reportedly in Colorado automatic fertilizer feeders attached to irrigation sprinkler systems are becoming increasingly popular. When the irrigation-well pump is shut off, water flows back through the pipe system into the well. This creates a partial vacuum in the lines that may cause fertilizer to flow from the feeder into the well. Even more serious is the suspicion that some individuals are dumping fertilizers directly into the well to be picked up by the pump and distributed to the sprinkler system. Such practices lead to direct ground water pollution and should be prohibited.

Animal Feedlots

Animal feedlots cover relatively small areas but provide a huge volume of animal wastes. These wastes have grossly polluted both surface and ground water resources with large concentrations of nitrate. Even small feedlots and liveries have created significant problems. In one situation infiltration of livestock wastes continued to pollute a public well more than 40 years after the livery stable was abandoned (Figure 21). In a few areas the liquid runoff from feedlots is collected in lined basins and pumped onto adjacent grounds as irrigation waters, providing a luxuriant growth.

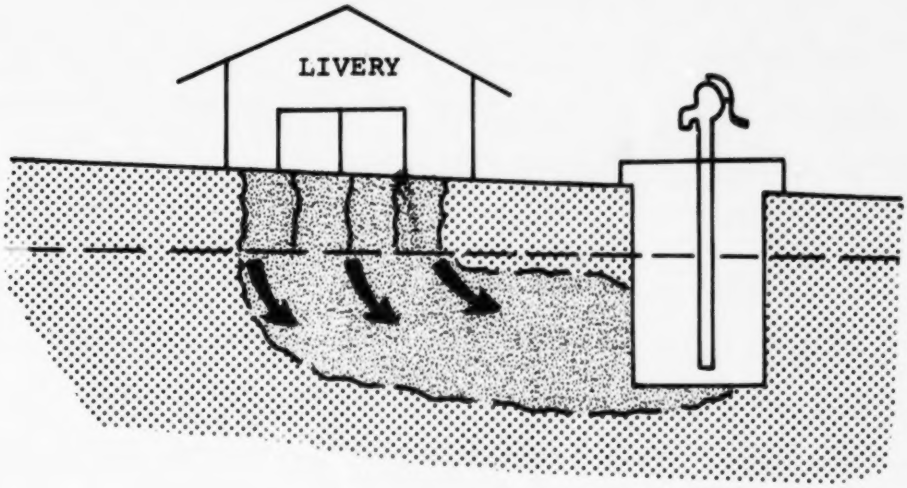


Figure 21. Many shallow wells have been contaminated by the infiltration of animal wastes.

Particulate Matter From Airborne Sources

A relatively minor source of ground water pollution is caused by the fallout of particulate matter originating as smoke, flue dust, or aerosols. Some of the particulate matter is water-soluble and toxic, and forms acid water. Long term environmental effects are unknown, largely because they have not been investigated. An example of this type of pollution is airborne chromium-rich dust that discharged through the roof ventilators of a factory in Michigan, accumulating on the downwind side of the plant. The highly soluble chromium compounds rapidly infiltrated and polluted a local municipal drinking water supply (Figure 22).

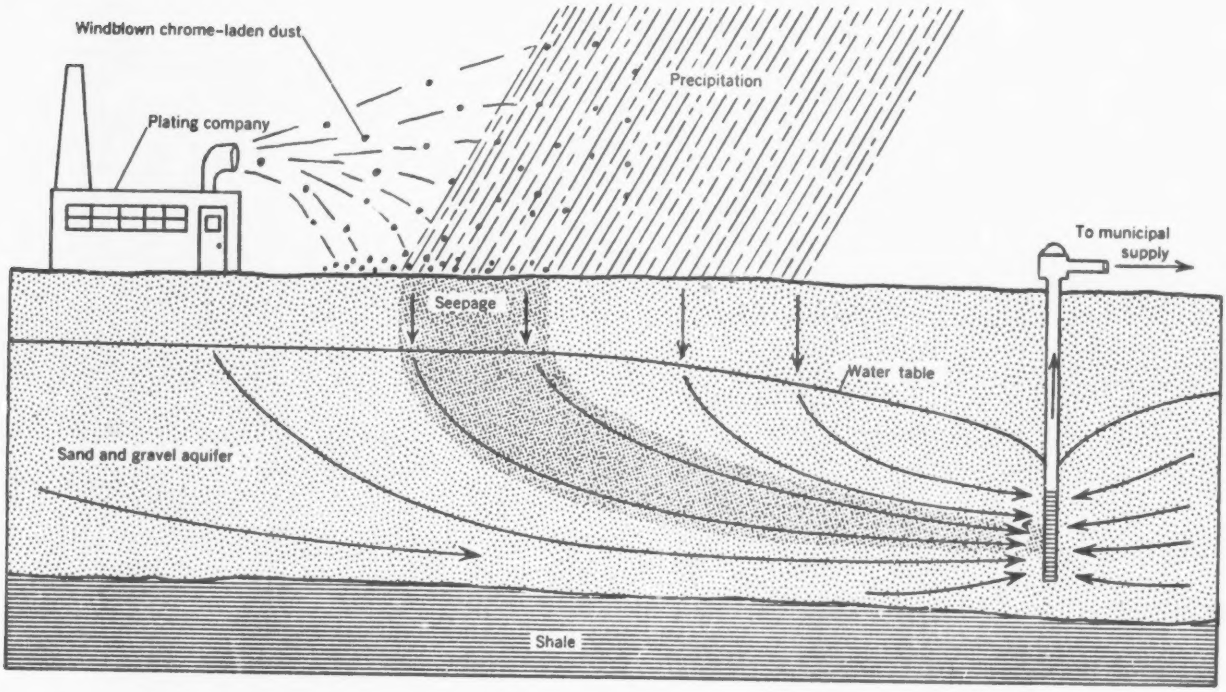

Windblown chrome-laden dust
Plating company
Precipitation
To municipal supply
Seepage
Water table
Sand and gravel aquifer
Shale

Figure 22. Air pollution can lead to ground water pollution. (From Deutsch, 1961)

The means of reducing water pollution problems caused by fallout of particulate matter is effective air pollution standards and control.

B. Ground Water Quality Problems Which Originate in the Ground Above the Water Table

Many different types of materials are stored, extracted, or disposed of in the ground above the water table. Water pollution can originate from many of these operations. Some of these, discussed in the following material, are:

1. Septic tanks, cesspools, and privies.
2. Holding ponds and lagoons.
3. Sanitary landfills.
4. Waste disposal in excavations.
5. Leakage from underground storage tanks.
6. Leakage from underground pipelines.
7. Artificial recharge.
8. Sumps and dry wells.
9. Graveyards.

Problems often originate in a water table aquifer from these sources because local laws are lax, they are not enforced, or because they do not exist.

Septic Tanks, Cesspools, and Privies

Probably the major cause of ground water pollution in the United States is effluent from septic tanks, cesspools, and privies (Figure 23). Individually of little significance, these devices are important in the aggregate because they are so abundant and occur in

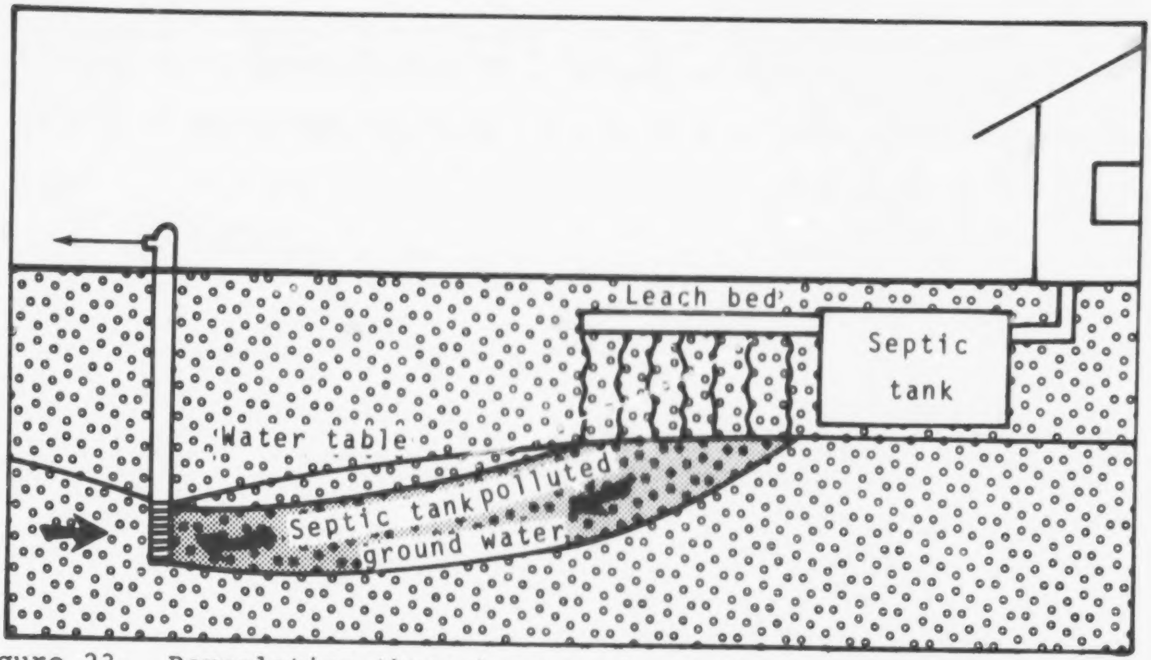


Figure 23. Percolation through zone of aeration. Most of the natural removal or degradation processes function under these conditions.

every area not served by municipal or privately owned sewage treatment systems. The area that each point source affects is generally small, since the quantity of effluent is small, but in some limestone areas effluents may travel long distances in subterranean cavern systems.

Most of the health problems that arise from this type of pollution are caused by the recycling of effluents through nearby water supply systems. This recycling effect was vividly exemplified during an investigation in Ohio in 1925 when several pounds of salt were poured into a privy. Within two weeks the homeowner's well water turned salty (Figure 24).

Water pollution problems related to septic tanks, cesspools, and privies can be controlled only with regulation of construction and installation of this type of device, and with adequate land use regulation, including limitations on the number of septic tanks per unit area.

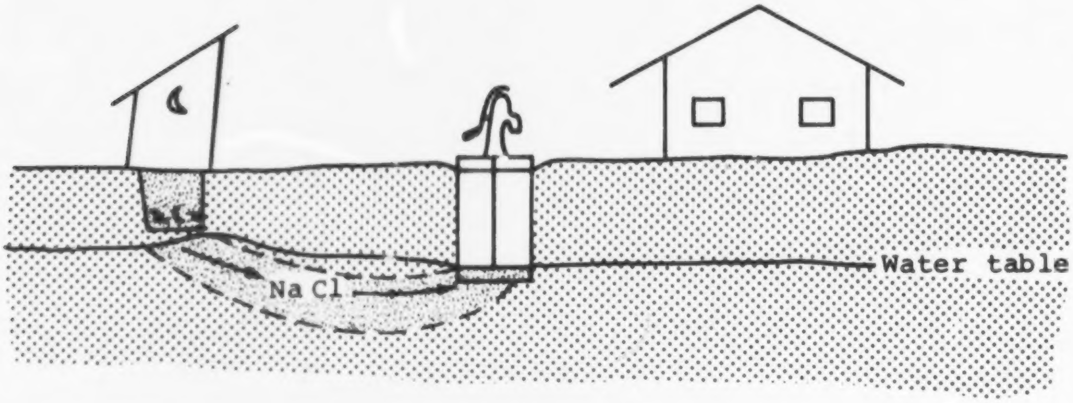


Figure 24. Shallow wells are commonly contaminated by effluent originating at cesspools and privies.

Holding Ponds and Lagoons

The second major source of ground water pollution is holding ponds and lagoons. These commonly consist of relatively shallow excavations that range in surface area from a few square feet to many acres. In some places they are euphemistically called "evaporation" ponds. Such ponds were commonly used to hold oil field brines, and when the pond floors became impermeable, the operators would disc them to increase infiltration. Holding ponds are also used to hold municipal sewage and to store large quantities of wastes including a wide variety of industrial chemicals. The latter wastes are generally characterized by highly concentrated solutions that may contain a wide variety of toxic compounds.

Special problems develop with holding ponds and lagoons in limestone terrain where extensive near-surface solution openings have developed. In Florida, Alabama, Missouri, and elsewhere municipal sewage lagoons have collapsed into sinkholes draining raw effluent into widespread underground openings. In some cases the sewage has reappeared in springs and streams several miles away. Wells producing from the caverns could easily become polluted and lead to epidemics of waterborne diseases.

Holding ponds are commonly considered to be liquid-tight but the vast majority leak large quantities of fluids, leading to relatively large polluted areas. Although rarely reported, at a large number of industrial sites ground water pollution by leaking holding ponds has been so extensive that all of the water supplies on the plant property are grossly polluted and unusable for many purposes without treatment. As a result, expensive treatment plants have been required. Moreover, the ground water may be so polluted that it exceeds surface water effluent standards and it cannot be pumped into adjacent streams.

Oil field brines, a highly mineralized salt solution, are particularly noxious and without doubt they have locally polluted both surface and ground water in every state that produces oil. The brine, an unwanted byproduct, is produced with the oil. In many states it is disposed of by placing it in holding ponds from which it infiltrates into the ground. Not uncommonly the oil well has been long abandoned before it becomes apparent that the adjacent ground water is polluted. This, in turn, may leave no possibility for recovery for damages by the landowner.

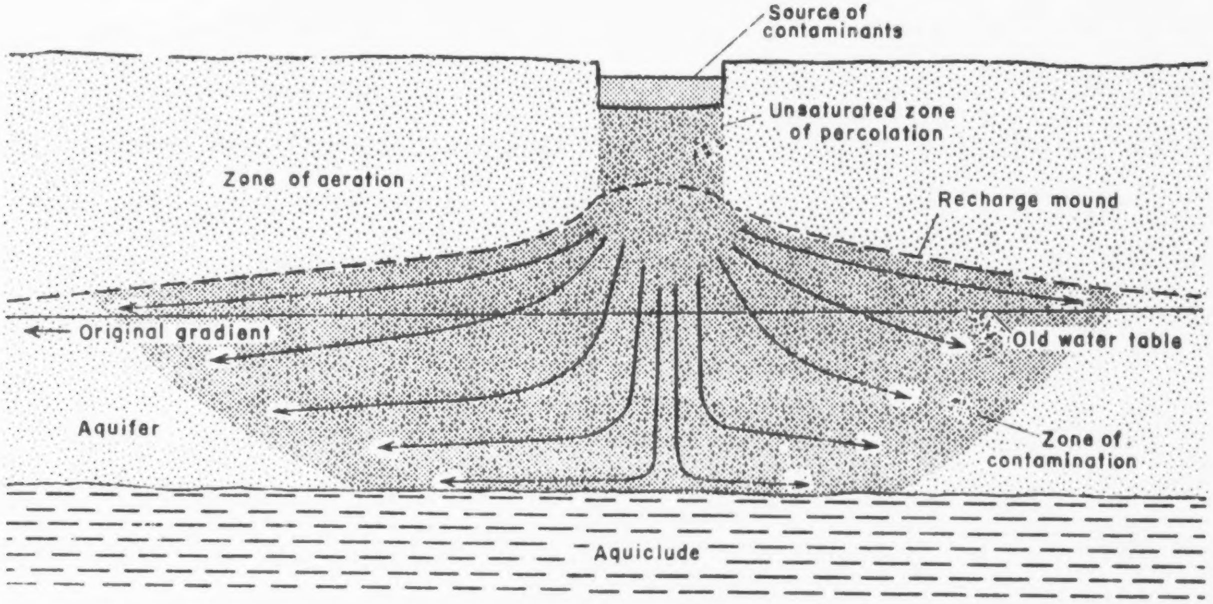

Source of contaminants
Unsaturated zone of percolation
Zone of aeration
Recharge mound
Original gradient
Old water table
Aquifer
Zone of contamination
Aquiclude

Figure 25. Schematic diagram showing percolation of contaminants through the zone of aeration and in an isotropic aquifer. (From Deutsch, 1965)

If adjacent ground water is not to be polluted, holding ponds and lagoons should be prohibited unless it can be shown, beyond a doubt, that fluids will not leak from them. In practice this would necessitate use of an impermeable lining such as heavy plastic. Clay linings have generally proved to be unreliable.

Sanitary Landfills

Sanitary landfills generally are constructed by placing wastes in excavations and covering the material with soil daily--thus the term "sanitary", to indicate that garbage and other materials are not left exposed to produce odors, smoke, vermin, and insects. Even though a landfill is covered, however, leachate may be generated by the infiltration of precipitation and surface runoff. Fortunately many substances are removed from the leachate as it filters through the unsaturated zone, but leachate may grossly pollute ground water and may even pollute streams if it discharges at the surface as springs and seeps.

At one site, rejected transformers and capacitors containing polychlorinated bi-phenols from an industrial plant were disposed of in a municipal landfill. A number of stillbirths and birth defects soon occurred in cattle that drank water from a nearby stream. Analyses of the water showed large concentrations of phenols, the origin of which was, without question, the landfill.

Pollution of ground water by landfills can be prevented by proper site location to prevent their use in places where leachate can readily enter ground water reservoirs, by regulation of their construction and operation, and by prohibiting the disposal therein of highly toxic wastes.

Waste Disposal in Excavations

Following the removal of clay, limestone, sand and gravel, or other material, the excavations created by removal of the material are commonly left unattended and often are used as unregulated dumps. The quantity and variety of materials placed in dumps and excavations are almost limitless. Excavations have been used for the disposal of a wide variety of liquid wastes, such as oil-field brines and spent acids from steel mills. Many also serve as disposal sites for snow removed from surrounding streets and roads -- snow that commonly contains a large amount of salt. Disposal of these and other wastes in excavations may lead to ground water pollution.

In the largest number of cases, waste disposal into excavations is not controlled. Pollution of ground water by this practice can be prevented by regulations similar to those for sanitary landfills.

Leakage from Underground Storage Tanks

A growing problem of substantial consequence is leakage from storage tanks and pipelines leading to such tanks. Gasoline leakage has caused severe hazardous pollution problems throughout the nation. Gasoline, being less dense, floats on the ground water surface and leaks into basements, sewers, wells, and springs, causing noxious odors, explosions, and fires.

Obviously, a leaky underground storage unit is difficult to detect and locate. Ground water pollution from this source could be minimized by periodic inspections of tanks, including pressure testing, and careful monitoring of fluid levels. Metal tanks could be replaced with tanks constructed or lined with noncorrodable material, such as fiberglass. Furthermore, tank-supporting substructures must be capable of sustaining the weight of loaded tanks in order to prevent settling, which may cause rupturing of pipelines leading to or from the tank.

Leakage from Underground Pipelines

Literally thousands of miles of buried pipelines crisscross the United States. Leaks, of course, do occur, but it may be exceedingly difficult to detect and locate them. They are more likely to develop in transmission lines carrying corrosive fluids. An example occurred in central Ohio where a buried pipeline carried oil field brine from a producing well to a disposal well. The corrosive brine soon weakened the metal pipe, which then began to leak over a length of several tens of yards. The brine infiltrated, polluting the adjacent ground water, then flowed down the hydraulic gradient and discharged into a stream. During the ensuing months, nearly all of the vegetation between the leaking pipeline and the stream was killed. The leaking area of the pipe was detected only because of the dead vegetation and salty springs.

A vexing problem of chromium compounds that polluted several shallow wells in Michigan was traced to a leaky sewer transporting metal finishing wastes. Radioactive materials have also leaked from pipelines. The several leaks reported at the Hanford A.E.C. Works came about as a result of loaded, underground tanks settling differentially into the subjacent earth materials, causing the pipelines carrying radioactive waste to break at joints. Such breaks are difficult to recognize until considerable spillage has occurred.

Artificial Recharge

Artificial recharge includes a variety of techniques used to increase the amount of water infiltrating to an aquifer. It consists of spreading the water over the land or placing it in pits, ponds, or wells from which the water will seep into the ground, or pumping water directly into the aquifer. As water demands continue to increase, there is no doubt that artificial recharge will become increasingly more popular as a means of providing a sustained yield.

Waters used for artificial recharge consist of storm runoff, irrigation return flows, stream water, cooling water, and treated sewage effluent, among others. Obviously the quality of water artificially recharged can have a major effect on the water in the ground.

Sumps and Dry Wells

Sumps and dry wells may locally cause some ground water pollution problems and in places where these structures are adjacent to a stream, bay, lake, or estuary, may pollute such surface water bodies and cause eutrophication, leading especially to a proliferation of the growth of algae and water weeds. These structures are commonly used to collect runoff or spilled liquids, which will infiltrate through the sump. Sumps and dry wells are typically installed to solve surface drainage problems, so they may transmit to ground water whatever pollutants are flushed into the well.

Graveyards

Leachate from graveyards may cause ground water pollution, although cases are not well documented. In some of the lightly populated glaciated regions in the north central part of the United States, graveyards are commonly found on deposits of sand and gravel, because these materials are easier to excavate than the adjacent glacial till and, moreover, are better drained so that burials are not below the water table. Unfortunately, these same sand and gravel deposits may also serve as major sources of water supply. Graveyards are also possible sources of pollution in many hard rock terrians where there are sinkholes or a thin soil cover.

An example of the persistence of earlier problems of this nature may be seen in the case of a gasworks on the south coast of England, where the presence of hydrogen sulfide in the plant well in the early 1950's was attributed to drainage from a 17th century Black Plague burial pit through which the well was bored.

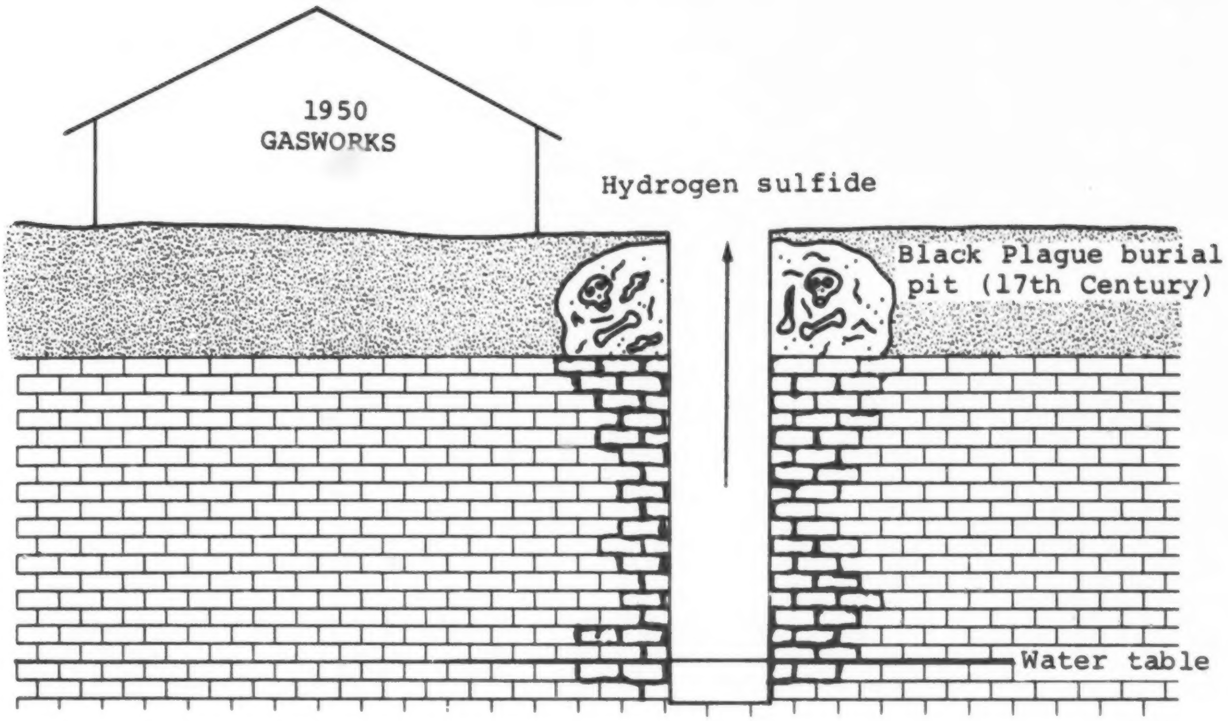

1950
GASWORKS
Hydrogen sulfide
Black Plague burial pit (17th Century)
Water table

Figure 26. A well on the south coast of England produced hydrogen sulfide originating from the leachate from an ancient human burial pit.

C. Ground Water Quality Problems That Originate In The Ground Below The Water Table

The following table lists a number of major causes of ground water pollution produced by the use and misuse of space in the ground below the water table.

1. Waste disposal in wet excavations.
2. Drainage wells and canals.

3. Well disposal of wastes.
4. Underground storage.
5. Secondary recovery.
6. Mines.
7. Exploratory wells.
8. Abandoned wells.
9. Water supply wells.
10. Ground water development.

Waste Disposal in Wet Excavations

Following the cessation of various mining activities, the excavations are commonly abandoned; eventually they may fill with water. These wet excavations have been used as dumps for both solid and liquid wastes. The wastes, being in direct connection with an aquifer, may cause extensive pollution. Furthermore, highly concentrated leachates may be generated from the waste due to seasonal fluctuations of the water table. In the late 1960's at a lead-zinc mine in northwestern Illinois, processing wastes were discharged into an abandoned mine working. The wastes, slowly moving in the ground water, polluted several farm wells. Analyses of water from several of the polluted wells showed high concentrations of dissolved solids, iron, hardness, sulfate, and, more importantly, heavy metals and cyanide. The disposal of water soluble waste materials in wet excavations clearly should be prohibited.

Drainage Wells and Canals

Where surficial materials consist of heavy clay, flat-lying land may be poorly drained and contain an abundance of marshes and ponds. Drainage of this type of land is generally accomplished with field tiles and drainage wells. A drainage well is merely a vertical, cased hole in the ground or in the bottom of a pond that allows the water to drain into deeper, more permeable materials (Figure 27). The pond water may be grossly polluted which, in turn, leads to deterioration of water quality in the receiving aquifer.

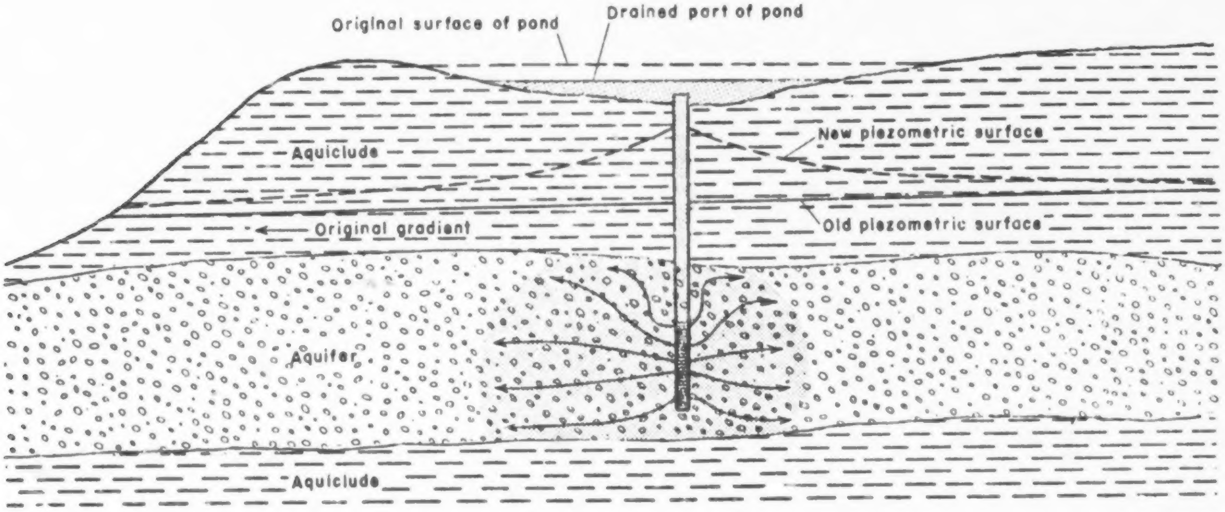

Original surface of pond
Drained part of pond
Aquiclude
New piezometric surface
Original gradient
Old piezometric surface
Aquifer
Aquiclude

Figure 27. Diagram showing drainage of a pond into an aquifer through a drain well.
(From Deutsch, 1965)

Deepening of stream channels may lower the water table. Where the fresh-saltwater interface lies at shallow depths, lowering of the water table (whether by channelization, pumping, or other cause) will induce upward migration of the saline water; it may even flow into the deepened channel and pollute the surface water (Figure 28). Reduction of the depth of the fresh water under these circumstances can result in a rise in the level of saline water several times greater than the distance the fresh water level is lowered. The physical principles that cause this are complex, and will not be explained here.

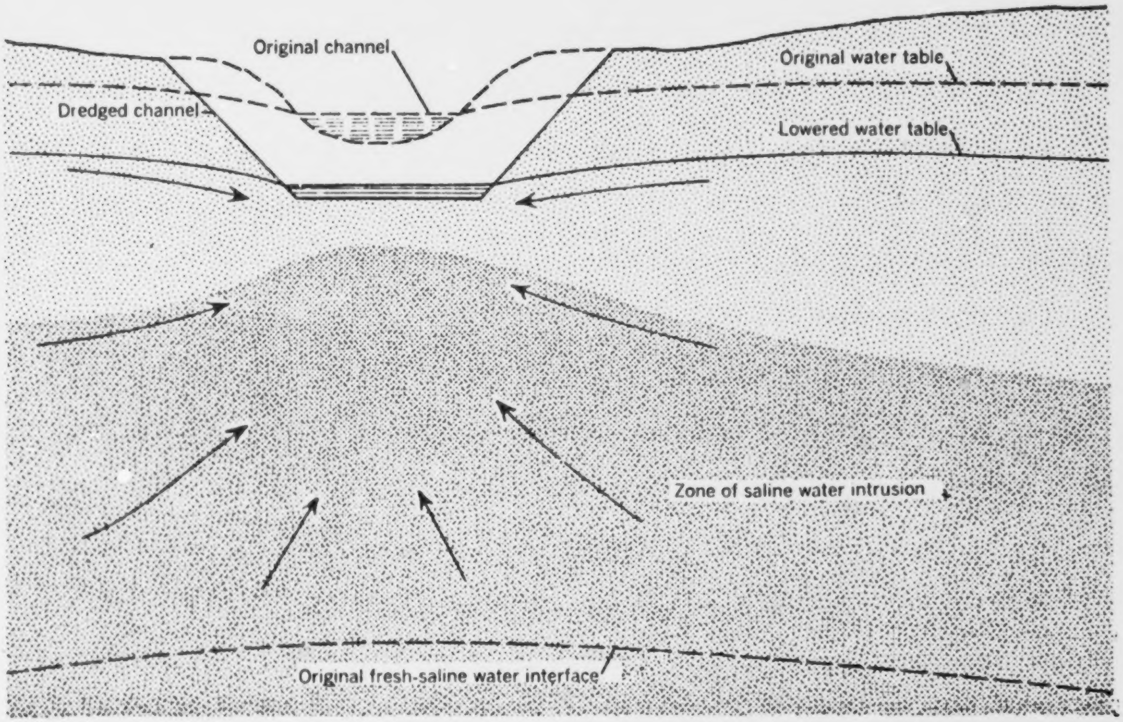

Original channel
Original water table
Dredged channel
Lowered water table
Zone of saline water intrusion
Original fresh-saline water interface

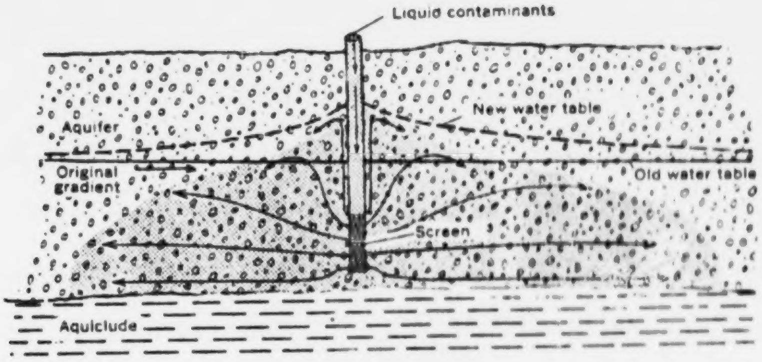
Figure 28. Diagram showing migration of saline water caused by lowering of water levels in an effluent stream and streamside aquifer hydraulically connected to an underlying saline water aquifer.
(From Deutsch, 1963)

In some coastal areas, particularly in Florida, the construction of extensive channel networks has permitted tidal waters to flow considerable distances inland. The salty tidal waters infiltrate, increasing the salt content of the ground water in the vicinity of the canal.

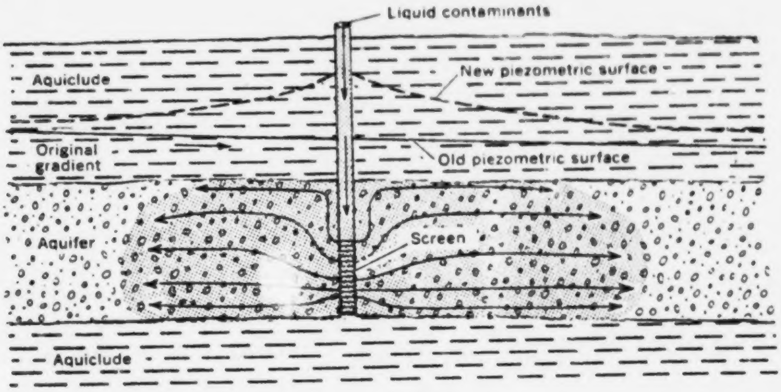
Well Disposal of Wastes

For decades, man has disposed of liquid wastes by pumping them into wells. Since World War II, a considerable number of deep well disposal projects have come into existence, usually at industrial sites. Industrial disposal wells range in depth from a few tens of feet to several thousand feet. The injection of highly toxic wastes into some of these wells has led to several water pollution problems. The problems are caused by the pollution of fresh water due to direct injection into the aquifer as well as leakage of pollutants from the well head, through the casing, or via fractures in confining beds. Injection of liquid wastes near Denver by means of deep well disposal apparently caused an increase in the frequency of local earthquakes. Deep well injection in the vicinity of Sarnia, Ontario, caused several long-abandoned brine wells in Michigan to flow because of the greatly increased aquifer pressure (Figure 29). In many states installation of new disposal wells is closely regulated, but probably thousands of abandoned wells are being used for waste disposal with no controls applied.

Properly managed and designed deep well disposal systems can be effectively used for storage of wastes deep underground and may permit recovery of the waste in the future. Before deep well disposal of wastes is permitted, however, there must be an extensive evaluation


Liquid contaminants
New water table
Aquifer
Original gradient
Old water table
Screen
Aquiclude

A. WATER-TABLE AQUIFER


Liquid contaminants
Aquiclude
New piezometric surface
Original gradient
Old piezometric surface
Aquifer
Screen
Aquiclude

B. ARTESIAN AQUIFER

Figure 29. Diagrams showing spread of contaminants injected through wells into water table and artesian aquifers. (From Deutsch, 1963)

of the well system, the waste fluids, and the rocks in the vicinity of the disposal well.

Underground Storage

The storage of material underground is attractive from both economic and technical points of view. Natural gas is one of the most common substances stored in underground reservoirs. However, the hydrology and geology of underground storage areas must be well understood in order to insure that the materials do not leak from the reservoir and pollute adjacent water supplies.

Secondary Recovery

With increased demands for energy resources, secondary recovery, particularly of petroleum products, is becoming increasingly more important. Methods of secondary recovery of petroleum products consist of injection of steam or waters into the producing zone, which either lowers the viscosity of the hydrocarbon or flushes it from the rocks, enabling increased production. Unless the injection well is carefully monitored and constructed, fluids can migrate from a leaky casing and pollute fresh ground water. This can be most effectively controlled by adequate secondary recovery design and operation regulations. It should be noted, however, that petroleum reservoir flooding may take thousands of gallons per minute of fresh or brackish water out of the hydrologic cycle throughout the United States.

Mines

Mining has caused a wide variety of water pollution problems. These are caused by pumping of mine waters to the surface, by leaching of the spoil material, waters naturally discharging through the mine, and by milling wastes, among others. Literally thousands of miles of stream and hundreds of acres of aquifers have been polluted by highly corrosive mineralized waters originating in coal mines and dumps in Appalachia. In many western states, mill wastes and leachates have seriously affected both surface water and ground water.

Many mines are deeper than the water table, and in order to keep them dry, large quantities of water are pumped to waste. If salt water lies at relatively shallow depths, the pumping of fresh water for dewatering purposes will cause an upward migration of the salt water, which may be intercepted by the well (Figure 30). The mineralized water most commonly is discharged into a surface stream. In order to protect ground water and surface water resources, mining activities must be regulated from their planning phase to final reclamation of the land.

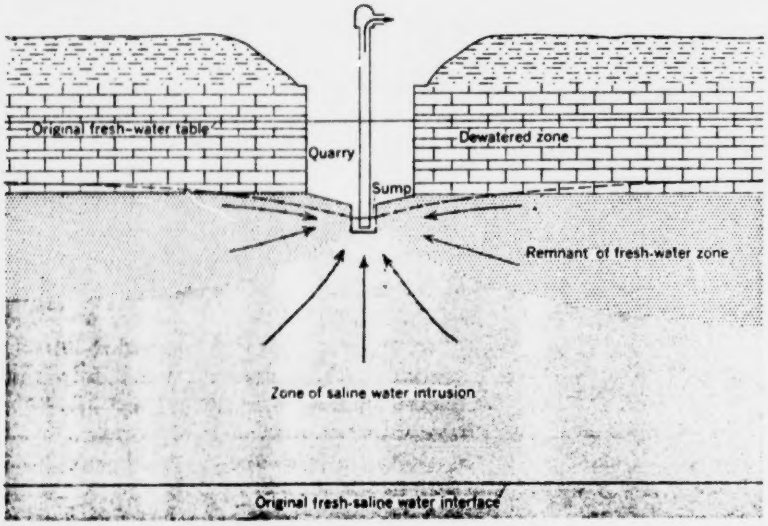

Original fresh-water table
Quarry
Dewatered zone
Sump
Remnant of fresh-water zone
Zone of saline water intrusion
Original fresh-saline water interface

Figure 30. Diagram showing migration of saline water caused by dewatering in a fresh water aquifer overlying a saline water aquifer.
(From Deutsch, 1963)

Exploratory Wells and Test Holes

Literally hundreds of thousands of abandoned exploratory wells dot the country side. Many of these holes were drilled to determine the presence of underground mineral resources (seismic shot holes, coal, salt, oil, gas, etc.). The open holes permit water to migrate freely from one aquifer to another. A fresh water aquifer could thus be joined with a polluted aquifer or a deeper saline aquifer, or polluted surface water could drain into fresh water zones (Figures 31 & 32).

Abandoned Wells

Another major cause of ground water pollution is the migration of mineralized fluids through abandoned wells (Figures 31 & 32). In many cases when a well is abandoned the casing is pulled (if there is one) or the casing may become so corroded that holes develop. This permits ready access for fluids under higher pressure to migrate either upward or downward through the abandoned well and pollute adjacent aquifers. In other cases, improperly cased wells allow high-pressure artesian saline water to spread from an uncased or partly cased hole into shallower, lower-pressure aquifers or aquifer zones, resulting in widespread salt intrusion.

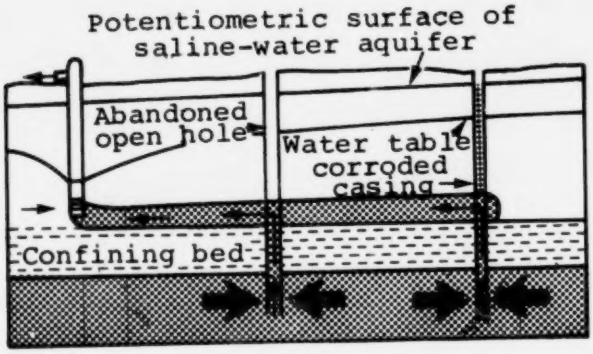

Potentiometric surface of saline-water aquifer
Abandoned open hole
Water table
corroded casing
Confining bed

Figure 31. Upward leakage and flow through open holes. Some important aquifers have been ruined by improper drilling practices.

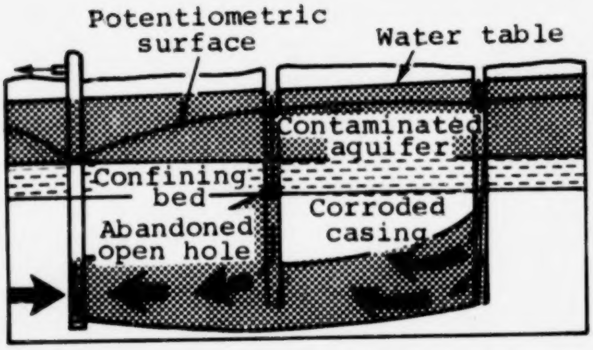

Potentiometric surface
Water table
Contaminated aquifer
Confining bed
Abandoned open hole
Corroded casing

Figure 32. Downward leakage. Contamination of one aquifer can affect others in a multi-aquifer system.

Water-Supply Wells

Improperly constructed water-supply wells may either pollute an aquifer or produce polluted water. Dug wells, generally of large diameter and shallow depth, and poorly protected, are commonly polluted by surface runoff flowing into the well. Other situations have been caused by infiltration of water through polluted fill around a well, and still others by barnyard, feedlot, septic tank or cesspool effluent draining directly into the well. A wide variety of pollution and health problems can arise because of poor well construction. These can be overcome, however, by the implementation of water well construction standards and by the training and licensing of water well drillers.

Ground Water Development

In certain situations pumping of ground water can induce significant water quality problems. The principal causes include interaquifer leakage, induced infiltration, and landward migration of sea water in coastal areas. In these situations the lowering of the hydrostatic head in the fresh water aquifer leads to migration of more highly mineralized water toward the well site. Undeveloped coastal aquifers are commonly full, the hydraulic gradient slopes towards the sea, and fresh water discharges from them through springs and seeps into the ocean (Figure 33). Extensive pumping lowers the fresh water potentiometric surface permitting sea water to migrate toward the pumping center. A similar predicament occurs in inland areas where saline water is induced to flow upward, downward, or laterally into a fresh water aquifer due to the decreased head (pressure) in the vicinity of a pumping well (Figure 34). Wells drilled adjacent to streams induce water to flow from them to wells. If the stream is polluted, induced infiltration will lead to deterioration of the water quality in the aquifer.

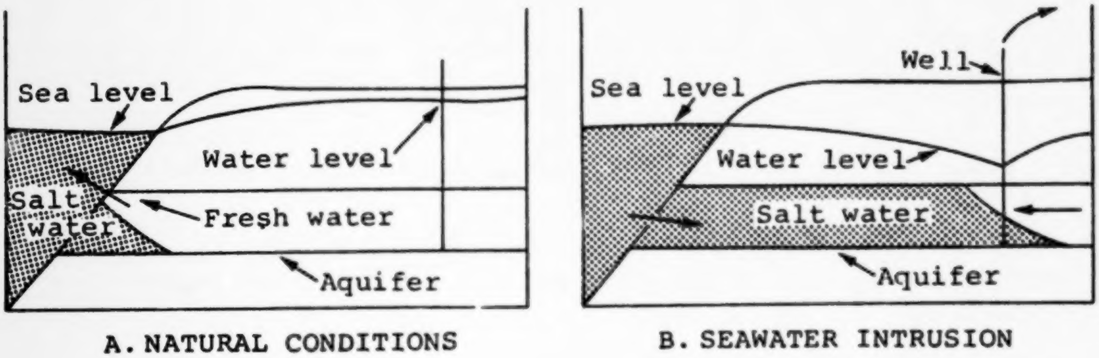

Sea level
Salt water
Water level
Fresh water
Aquifer
A. NATURAL CONDITIONS
Well
Sea level
Water level
Salt water
Aquifer
B. SEAWATER INTRUSION

Figure 33. Sea water intrusion is caused by overpumping of coastal aquifers.

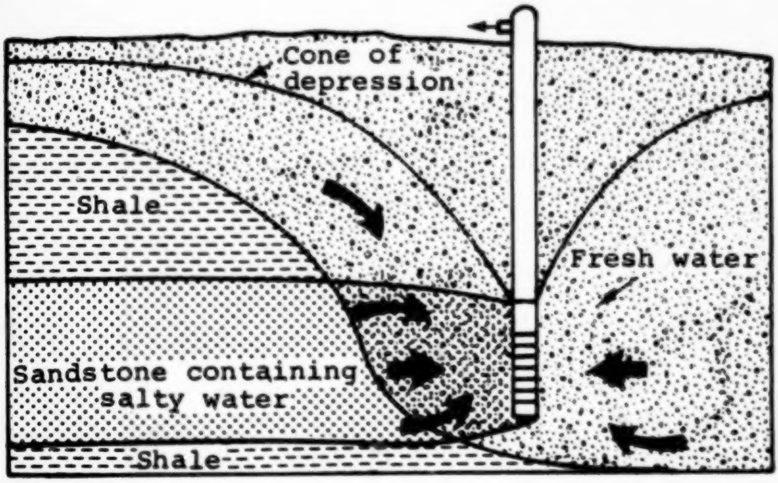

Cone of depression
Shale
Fresh water
Sandstone containing salty water
Shale

Figure 34. Diagram showing how a pumping well can induce highly mineralized water to flow from a saline aquifer into a fresh water aquifer.

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CHAPTER II

SURVEY OF REGULATORY PROVISIONS AFFECTING GROUND WATER QUALITY

Control of water pollution logically includes both water in streams and water in the ground; they are interconnected bodies of water that affect and support one another. And yet these two phases of water present largely different problems in water pollution control. A polluted stream may be "cleaned up" by vigorous enforcement of laws enacted after the problem is recognized. A ground water source, on the other hand, in effect may be permanently spoiled if pollution is not prevented.

Complicating the problem in ground water pollution is the difficulty of monitoring and stopping pollution. A state agency can monitor the streams of the state to determine where surface water pollution is occurring, and can place limits on discharges into these streams. A similarly direct monitoring and limitation of ground water pollution is not possible. Ground water pollution can occur almost anyplace, it can occur much more secretly, and measurement of its impact on ground water is usually impossible within the time in which action must be taken to avoid permanent damage.

Thus, unlike the thrust of the regulatory effort to control pollution of streams (as in current federal and state water pollution control laws), laws and regulations to prevent ground water pollution do not center around a single permit system but are directed at a variety of activities each requiring a special type of expertise and administrative structure. For example, prevention of ground water pollution from solid waste or septic tank leachate requires an expert's knowledge of geology and soils and of their ability to absorb such leachate, applied to regulation of the individual sites that produce it; prevention of ground water pollution from water or oil well drilling requires an expert's knowledge of those subjects, applied to regulation of the individual activities that may cause it.

Statutes and regulations which protect ground water reflect the difficult and complex nature of ground water pollution control. In order to give some order to a description of state controls, so that the reader may more readily comprehend the subject, the material in the following chapter is presented under the headings of ten "control points", as follows:

1. Surface Water Standards II-6
2. Land Use Regulations II-13
3. Control of Waste Disposal Sites II-17
    a. Solid Waste Disposal II-17
    b. Individual Sewage Systems (septic tanks) II-28
    c. Animal Feedlots II-36
    d. Deep Well Disposal of Wastes II-45
    e. Other Well Disposal of Wastes II-56
4. Management of Water Levels and Pumping Rates II-57
5. Control of Well Construction and Operation II-94
    a. Water Wells II-94
    b. Oil and Gas Wells II-101

6. Air Quality Standards II-111

7. Control of Land Spreading of Potential Pollutants II-112

    a. Irrigation Using Waste Water II-112

    b. Land Disposal of Wastes II-118

    c. Other Substances II-122

8. Control of Storage Areas II-123

    a. Storage of Waste II-123

    b. Storage of Materials other than Waste II-129

9. Control of Mining and Quarrying II-132

10. Control of Transportation and Handling of Fluids II-134

    a. Surface Pipelines II-134

    b. Sewers II-134

    c. Spills II-135

One thing that the reader may perceive from this list is that control points that can effect protection of ground water are typically not primarily designed to do so. Surface water standards, for example, which are established for streams and rivers, have a substantial effect on ground water quality by improving the quality of stream water that infiltrates into adjoining aquifers. Likewise, control of air pollution affects ground water because particulate matter (smoke) falls to the ground over a wide area, to be dissolved by rainfall or snowmelt and enter the soil and possibly an aquifer below. Land use regulations, as in local zoning, can be used to protect ground water by preventing location of polluting activities in areas where ground water pollution is likely--e.g., location of lagoons or solid waste disposal sites in flood plains, or use of septic tanks where soils are thin.

Even where a regulatory scheme is designed with ground water protection in mind, it is usually only one of several objectives. Solid waste disposal regulations typically have provisions specifically concerning ground water, yet their primary purpose is a more general one of preventing health hazards and nuisances--disease, rats, smoke, odors, unsightliness, etc. Septic tank regulations are primarily designed for similar reasons--to prevent location or operation that can result in pollution of nearby wells, or surface drainage that can cause disease or nuisances. Some water well regulations bear no indication of an intent to prevent pollution of ground water resources in the area of the well, but appear designed solely to prevent entry of pollutants into the water that the user receives from the well; nevertheless, proper construction of a well may prevent pollution of an aquifer. Even in regulation of deep well disposal of wastes, ground water protection is only one consideration--others are prevention of damage to mineral deposits, prevention of the possibility of escape to toxic pollutants to the surface, and prevention of earthquakes.

More subtle is the role of an activity such as management of water levels and pumping rates. Generally, one thinks of this "control point" as bearing only on allocation of rights to use water. However, near a seacoast, uncontrolled pumping may cause salt water intrusion into fresh water aquifers; inland, pollution may occur as heavy pumping induces polluted water or highly mineral or saline waters to enter unpolluted aquifers. In any area where ground water pollution has occurred, from stream infiltration or from any of a number of sources, pumping may cause pollutants to move into unpolluted aquifers, causing damage to the water resource that, as a practical matter, may be irreversible. To control this aspect of ground water pollution, a state must be able to control water use where it needs to.

Under some of the control points, there is little or no regulation to refer to. States have not generally begun to regulate land spreading of potential pollutants (Control Point 7) or storage areas (Control Point 8). These are areas in which the hazard to ground water is expected to increase as enforcement of stream standards improves under the Federal Water Pollution Control Act Amendments of 1972--if a person is stopped from discharging waste into streams, he is likely to store or spread it on the ground as the simplest alternative in dealing with it.

Other potential causes of ground water pollution that appear generally to be unregulated include leakage from buried gasoline storage tanks, spreading of chemicals (e.g., salt) on highways, leaching from storage piles such as salt or industrial materials, leakage from sewer lines, spreading of agricultural chemicals, and accidental spills of hazardous materials. Information is lacking as to the seriousness of the threat posed generally by these sources, although it is evident that in a particular case, any of them could seriously affect an aquifer.

Such a list of unattended potential problems also suggests the variety of agency involvement that may be required in preventing ground water pollution. Gasoline storage is normally a responsibility of the State Fire Marshal's Office; highway salting comes under a Department of

Highways; sewer lines under a Department of Health or an EPA; and agricultural chemicals under a Department of Agriculture. The entire list of control points (above) suggests involvement of other agencies--an agency that regulates oil and gas production, another that regulates mining, various state water resources and natural resources agencies, an air pollution control agency, planning and zoning agencies, and various local agencies and subdivisions of government.

The following description does not allude to all the regulations of all the states, nor is it intended to set forth the best or even average examples of regulations of the various types presented. It is intended only to illustrate the range of existing controls applicable to ground water pollution and, by reference to principal types of existing and proposed regulations, to suggest types of controls that are available.

Control Point 1: SURFACE WATER STANDARDS

Standards for control of the quality of water in streams, rivers, lakes, swamps and other surface accumulations of water are controlled by federal and state laws and regulations. Each state has a statute directed at this type of control. Since the enactment of the Federal Water Pollution Control Act Amendments of 1972 (Public Law 92-500), however, the states have had to conform their statutes and regulations to federal requirements.

The federal law declares a national goal of elimination of the discharge of pollutants into navigable waters by 1985. A state that wishes to handle issuance of water pollution control permits under the federal system (the National Pollutant Discharge Elimination System) must enact a statute in compliance with the federal requirements.

A central aspect of the federal law, requiring an important change in existing state laws, is the establishment of effluent standards. Thus, rather than using effect of a particular pollution source on the receiving water as the measure for limiting discharges, it attempts to enforce stream quality standards by setting limitations on all discharges into navigable waters. By July 1, 1977, effluent limitations for point sources other than publicly owned treatment works are to be achieved which shall require the application of the best practicable control technology currently available. (A "point source" under the federal law is "any discernible, confined and discrete conveyance, including but not limited to any pipe, ditch, channel, tunnel, conduit, well, discrete fissure, container, rolling stock, concentrated animal feeding operation, or vessel or other floating craft, from which pollutants are or may be discharged.")[1] For publicly owned treatment works, effluent limitations are based on secondary treatment. There are also effluent limitations on discharges into publicly owned treatment works.

For a state program to be approved so that it may handle issuance of water pollution control permits, it must have an approved planning process, the program must conform to guidelines for minimum procedural and other requirements for state programs, and the EPA Administrator must approve the state's permit program. For a state program to be approved, in addition to specified procedural and enforcement requirements, it must:

1. Authorize inspection, monitoring, entry, and reporting re-requirements as extensive as those authorities of the EPA Administrator;
2. Contain adequate authority to abate violations, including civil and criminal penalties;
3. Require permits for publicly owned treatment works to contain conditions requiring adequate notice of new introductions into the works of pollutants from any source and notice of substantial changes in volume or character;
4. Ensure that industrial users of public treatment works are paying the applicable user charges, complying with pretreatment requirements, and with monitoring, reporting, and record keeping requirements;
5. Through its permit program, ensure compliance with effluent and other limitations, with national standards of performance, and with pretreatment requirements.

A model law to enable states to participate in the National Pollutant Discharge Elimination System has been proposed by the Council of State Governments.[2] The law prohibits discharge of pollutants other than in compliance with the law, then authorizes the agency to issue permits for the discharge of pollutants upon condition that the discharge meets applicable state and federal water quality standards and effluent limitations. Two principal provisions of the act are:

General Terms and Conditions of Permits

a. The Director is authorized to require as conditions in permits issued under this Act the achievement of:

   1. effluent limitations based upon the application of such levels of treatment technology and processes as are required under the Federal Water Pollution Control Act, as amended.

   2. any more stringent effluent limitations necessary to meet water quality criteria established pursuant to any state or federal law or regulation.

b. Effluent limitations prescribed under subsection (a.) of this section shall be achieved in the shortest reasonable period of time consistent with state law and the Federal Water Pollution Control Act, as amended, and any regulations or guidelines promulgated thereunder.

c. The Director is further authorized to: (1) set and revise schedules of compliance and include such schedules within the terms and conditions of permits for the discharge of pollutants; and (2) prescribe terms and conditions for permits issued under this Act to assure compliance with applicable state and federal effluent limitations and water quality criteria, including requirements concerning recording, reporting, monitoring, entry and inspection to the extent permissible under sections 13 and 14 of this Act, and such other requirements as are consistent with the purposes of this Act.

Prohibition Against Issuing Permit in Certain Instances

No permit shall be issued authorizing any of the following discharges:

a. The discharge of any radiological, chemical, or biological warfare agent or high level radioactive waste;

b. Any discharge which the Secretary of the Army, acting through the Chief of Engineers, finds would substantially impair anchorage and navigation of any waters of the United States;

c. Any discharge to which the Administrator of the U.S. Environmental Protection Agency, or his designee, has objected pursuant to any right provided to the Administrator under the Federal Water Pollution Control Act, as amended;

d. Any discharge which is in conflict with an area-wide waste treatment management plan approved under the Federal Water Pollution Control Act, as amended.

The federal law applies to "navigable waters" which are defined as "waters of the United States". State laws typically apply to all waters of the state, including ground water; the extent to which the federal law may be applied to ground water is not clear. In requiring improvement of the quality of navigable waters, the federal law will, in fact, have an effect on the quality of ground water because it will improve the quality of water entering the ground by infiltration from the surface. The U. S. EPA has also identified some specific controls on activities affecting the quality of ground water, as follows:[3]

1. The EPA will establish ground water criteria for treatment works it funds.
2. It will structure its permitting, planning, and research to provide states with the maximum incentive to establish full ground water regulatory programs of their own, including ground water monitoring.
3. Effluent guidelines (applicable to point source discharges into navigable waters) will be developed with appropriate reference to the potential for ground water pollution that may result from the use of a particular treatment technology.
4. Dischargers which contemplate a change from direct discharge to land disposal or employ a combination of discharge and land disposal, as part of a program to comply with the effluent limitations of a permit, will be given permits containing conditions to minimize the damage to underground and surface water resources. (It has been observed that the federal law was not intended to purify surface water at the expense of ground water.)
5. Municipal permits will require municipal regulatory controls to protect ground water from facilities presently connected into a municipal sewer system but which, because of pretreatment, user charge, or cost recovery requirements, change to a land disposal technique. Conditions will also

be set for pretreating industries which use publicly owned treatment works.

6. Grants for construction of publicly owned treatment works employing land disposal or aquifer recharge will be contingent on the design of the project to meet specific ground water quality standards. The same criteria may be applied to industry.
7. The Act requires any areawide planning process to include a process to control disposition of all residual waste generated in the area, including surface or subsurface disposal, to protect ground water quality. (Currently, the EPA has produced a draft of guidelines for land disposal of wastes.)
8. The Act requires that for a state to maintain federal approval of its program, it must either prohibit the disposal of pollutants into wells, or control such disposal in order to prevent pollution of ground and surface water resources and to protect the public health and welfare. (The EPA adopted a "Policy on Subsurface Emplacement of Fluids by Well Injection" on April 2, 1974. See also reference to the Safe Drinking Water Act, below.)
9. The EPA will conduct research on pathways of ground water pollution; states will be required to report on ground water under the requirement of the act that each state report annually on non-point sources of pollution; states may be assisted in establishing ground water monitoring systems.

In any examination of federal EPA authority concerning ground water, reference should be made to the SAfe Drinking Water Act of 1974 (Public Law 93-523). Essentially directed at assuring that public water systems are adequately supervised by the states to assure safe drinking water, the Act also gives the EPA Administrator the duty to adopt regulations for state underground injection programs, and authorizes him in an emergency to take whatever action he deems necessary to protect health where a contaminant is likely to enter a public water system.

Control Point 2: LAND USE REGULATIONS

Land use regulation involves making a determination as to a best allocation of activities, prohibiting certain activities in areas where they would tend to be detrimental to the public health, safety, and welfare. Flood plain zoning is a natural resource related type of land use regulation intended to preserve life and property by controlling development in areas subject to flooding. Even in establishing conventional urban zoning, natural resources may be protected or preserved for utilization if the plan upon which the zoning is based takes into consideration the presence of water resources, scenic areas, mineral deposits, etc. Water and air pollution problems may be avoided by considered location of certain industrial activities, by prohibiting unsewered development in areas where the topography or soil types will be likely to result in water pollution if septic tanks are used, or by prohibiting location of solid waste disposal sites or waste lagoons in areas where the likelihood of their causing ground water pollution is unreasonably high. Zoning has been proposed as a means of preventing especially critical ground water recharge areas from being covered by buildings, parking lots, and roads.

A number of states have recently enacted statutes to regulate land use to protect natural features such as shorelines and wetlands. Others have enacted statewide land use laws with more general objectives of requiring wise development and preserving natural resources. The statutes typically include protection of water quality as one of their objectives.

California's Coastal Zone Conservation Act is designed to protect the coastal zone as "a distinct and valuable natural resource belonging to all the people and existing as a delicately balanced ecosystem."[4] A narrow part of the zone, extending from the seaward limit of the state's jurisdiction to a line 1,000 yards landward from the mean high-tide line, is designated the "permit area" in which one must obtain a permit in order to subdivide, to build a structure, to grade, dredge, etc., dispose of any waste, or change the intensity of use of water, the ecology related thereto, or access thereto. To obtain a permit, the applicant must show that the development will not have any substantial adverse environmental or ecological effect, and that the development is consistent with the declarations and objectives of the law.

Under Florida's Environmental Land and Water Management Act of 1972, an "area of critical state concern" may be designated for an area having a significant impact upon environmental, historical, natural, or archeological resources of regional or statewide importance; an area affected by a major public facility; or a proposed area of major development potential.[5]

In such an area, local land development regulations must comply with principles for guiding development specified under the rule designating the area. The law also controls "developments of regional impact"--any development which would affect the health, safety, or welfare of citizens of more than one county. One of the considerations required to be used in adopting guidelines and standards for such a development is the extent to which the development would create or alleviate environmental problems such as air or water pollution or noise.

Another type of environmental land use law that can affect ground water is the "wetlands" statute, such as those of Delaware, New York, and Wisconsin. The Delaware statute, for example, identifies the following needs for protecting wetlands:[6]

1. The wetlands are sources of nutrients to marine life of economic value;
2. The wetlands are habitats for plants and animals of significant economic and ecological value necessary to marine commerce, recreation and aesthetic enjoyment;
3. Wetlands reduce flood damage and they absorb silt, thus preventing silting of harbors and navigation channels.

The statute defines wetlands as marshes, swamps, and other lowlands along the coast that are subject to tidal action, and certain contiguous areas where fresh water stands most of the time due to high water table and which contribute significantly to ground water recharge. Activities in the wetlands require a state permit, one of the factors in issuance of which is the effect of site preparation and the proposed activity on the quality and quantity of tidal waters, and surface and ground water resources.

A few states have statewide land-use laws. Under the Maine Land Use Law, for example, a commission appointed by the Governor establishes three types of districts in the unorganized (non-municipal) portions of the state: Protection (where development would jeopardize significant natural, recreational, and historic resources, including flood plains, precipitous slopes, wildlife habitat, and other areas critical to the ecology of the region or state); Management (forest, agriculture); and Development (industry, residential areas, removal of minerals).[7] A permit must be obtained from the state to sell lots or perform construction in such areas.

Land use standards adopted by the commission are (among other things) to encourage the most desirable and appropriate use of air, land, and water resources consistent with the comprehensive land use plan; reduce water pollution and other environmental intrusions; and reflect a consideration of the availability and capability of the natural resources base. Criteria for approval of a permit application include requirements that:

1. Adequate technical and financial provision has been made for meeting the state's air and water pollution control standards, for solid waste disposal, for controlling of offensive odors, and for the securing and maintenance of sufficient healthful water supplies;
2. Adequate provision has been made for fitting the proposal harmoniously into the existing natural environment in order to assure there will be no undue adverse effect on existing uses, scenic character, and natural and historic resources in the area;
3. Uses of topography, soils, and subsoils meet standards of the current Soil Suitability Guide for Land Use Planning in Maine, or which are adaptable to the proposed use pursuant to said guide and will not cause unreasonable soil erosion or reduction in the capacity of the land to absorb and hold water.

Control Point 3: CONTROL OF WASTE DISPOSAL SITES

A. Solid Waste Disposal

Most states have statutes that prohibit disposal of solid waste without a permit from either a local or state agency. The statutes typically authorize a state agency to adopt regulations, and leave it to the adopting agency to set requirements for the varying conditions that may exist.

An example of brevity is the Minnesota statute, which requires the pollution control agency to adopt standards for the control of the collection, transportation, and disposal of solid waste for the prevention and abatement of water, air, and land pollution, "recognizing that due to variable factors, no single standard of solid waste control is applicable to all areas of the state".[8] The agency is instructed to take into consideration physical conditions, topography, soils and geology, climate, transportation, and land use; the standards are to be "premised on technical criteria and commonly accepted practices". A similar provision authorizes adoption of regulations relating to collection, transportation, disposal, equipment, location, procedures, methods, systems, or techniques.

Other statutory provisions typically relate to inspection and enforcement authority, penalties, and appeals. The statute also will contain definitions so that the scope of the agency's authority is defined, including specification of the types of waste included (garbage, rubbish, demolition materials, etc.).

Typical regulations cover information and other requirements for obtaining a permit, site selection, specifications concerning proximity of water resources, prohibited types of disposal, and construction, equipment, operation, reporting, monitoring, and closing requirements.

Information and Other Requirements for Obtaining a Permit

The regulations typically require, as a condition for issuance of a permit:

1. Plans and specifications for the proposed site and facility; some states require that these be prepared by a registered professional engineer.
2. A map or aerial photograph of the area showing land use within the adjoining area. Locations of water wells may be required. Delaware requires wells within one mile of the site to be identified, but the requirement in other regulations is usually less than this, down to 500 feet.[9]
3. A report on geologic formations and soil conditions (the Wisconsin regulation specifies three borings for a site up to five acres in size, one boring for each additional five acres up to 50 acres, and one boring for each additional 50 acres),[10] including depth to ground water. The Florida regulation additionally requires a hydrologic survey.[11] Illinois requires data describing soil classification, grain size distribution, permeability, compactability, and ion-exchange properties of the subsurface materials for those strata essential to design of the landfill; comprehensive analysis of water samples from on-site and nearby wells; and a description of ground water conditions including flow below and adjacent to the proposed site, with an appraisal of the effect of the landfill on ground and surface waters.[12]
4. A description of surface drainage patterns. The California regulation requires calculations for the flooding frequency of streams within or adjacent to the site.[13]
5. A report of:

   a. Population and area to be served by the facility;
   b. Anticipated type, quantity, and source of wastes;
   c. Source and characteristics of cover material;
   d. Type and amount of equipment, and operating plans;

6. Information concerning measures proposed for prevention of water pollution and for control of drainage, leachate, and gases.

Frequently, the statute or regulation will require that a representative of the regulating agency inspect the site prior to issuance of license.

Some regulations also require a statement or plan as to ultimate use of the site after closing.

The Michigan statute requires that the applicant for a license be a "responsible and suitable person to conduct the business".[14] That statute also requires a surety bond of $500 per acre for the proposed site, with a minimum of $2,500.

Statutes often exempt dumping by a person of his own wastes on his own property.

Site Requirements

California's regulation classifies sites according to types of waste that are acceptable.[15] A "Class II" site, for instance, is for garbage, rubbish, construction and demolition materials, street refuse, etc. Such a site overlying usable ground water must be "naturally capable of preventing lateral and vertical hydraulic continuity between liquids and gases emanating from the waste in the site and usable surface or ground waters, or the disposal area has been modified to achieve such capability"; or, if the site does have vertical and lateral continuity with usable ground water, then "geological and hydraulic features such as soil type, artificial barriers, depth to ground water, and other factors will assure protection of the quality of usable ground water."

Such a site must also meet the following criteria:

1. Protected by natural or artificial features so as to assure protection from any washout and from inundation which could occur as a result of tides or floods having a predicted frequency of once in 100 years.
2. Surface drainage from tributary areas shall not contact wastes in the site during disposal operations for the active life of the site.
3. Gases and leachate emanating from waste in the site shall not unreasonably affect ground water during the active life of the site.
4. Subsurface flow into the site and the depth at which water soluble materials are placed shall be controlled during construction and operation of the site to minimize leachate production and assure that the waste material will be above

the highest anticipated elevation of the capillary fringe of the ground water.

Class I sites, for toxic wastes, are subject to considerably more severe restrictions. Class III sites, for inert materials, are much less restricted.

Some site restrictions in regulations are phrased as prohibitions. The Florida regulation, for example, prohibits disposal (unless approved by the department):

1. In a body of water or in the watershed of a surface public water supply where runoff or leachate may result in violation of pollution control laws or regulations;
2. On the banks of a stream connected to the Floridan aquifer;
3. In a sinkhole;
4. In a limestone or gravel pit;
5. In an area subject to flooding (unless approved drainage is installed);
6. Where the water table is less than five feet below the normal ground surface;
7. In an area immediately adjacent to or within the cone of influence of public water supply pumping;
8. Within 200 feet of a habitation or place of business served by a public water supply, or within 1,000 feet of one that depends upon a shallow well supply.[16]

The Michigan guidelines provide minimum setback distances from bodies of water.[17] They specify also that in permeable soils, at least 2,000 feet isolation should be maintained, in the direction of ground water movement, from properties where domestic wells exist or may be drilled. For large capacity wells, additional isolation may be required. The Michigan guidelines, as do regulations of other states, contain several specifications for various types of soil, bedrock, and water situations. The Minnesota regulation prohibits location of a solid waste disposal site within one mile of a municipal well or water intake.[18] A number of regulations require a minimum vertical distance to ground water, ranging from two feet in Delaware[19] to ten feet in Minnesota and Wisconsin.[20]

Hazardous Wastes

The regulations contain special provisions for disposal of hazardous wastes, such as toxic substances. Generally, the statute or regulation defines the category and prohibits disposal in a solid waste site without specific approval of the agency. They frequently require that such wastes be disposed of in a separate area, or that they be neutralized, if possible.

The California regulation controls disposal of hazardous wastes by its system of categorizing types of disposal sites, wherein only the "Class I" site may receive such wastes.[21] Requirements for such a site are strict, requiring in effect that there be no possibility of liquids reaching water resources either downward or through inundation or washout.

The Wisconsin regulation applies special provisions to toxic and hazardous wastes, including quarterly reports of the quantities and types of such wastes disposed of at the operation during the previous calendar quarter, the requirement that wells be provided at locations specified by the department, and that samples from these wells be collected and analyzed quarterly.[22] This regulation requires as a condition for obtaining a permit to dispose of toxic or hazardous wastes that the applicant (among other things) provide a list of chemical and trade names of all wastes, names and addresses of initial sources and transporters, and a report of the average quarterly waste quantities in both pounds and gallons to be disposed of at the site.

The Oregon statute requires that an applicant for a permit to operate a waste disposal site to receive "environmentally-hazardous wastes" must as a condition of issuance of the permit, convey the land to the state. The statute prohibits disposal of hazardous wastes other than upon real estate owned by the state.[23]

Other Requirements in Solid Waste Laws and Regulations

The regulations contain requirements for operation of disposal sites, such as the amount and frequency of covering and compaction as wastes are deposited, method of filling, placement of impermeable barriers, grades, method of confining windblown material, and requirements for fences, roads, signs, and screening by vegetation.

The statutes or regulations typically prohibit open burning and open dumping without covering. They require that dust, insects, and vermin be effectively controlled, and that fires be prevented.

The regulations frequently require that surface drainage be diverted from the working area. Some regulations require that surface runoff from a site be treated to comply with water pollution control standards.

A number of regulations require installation of monitoring wells, but leave to the administering agency the decision as to when and where this is required, on an individual site basis. Pennsylvania requires at least one well in each dominant direction of ground water movement.[24]

The Florida regulation requires that where the gas generated by the decomposition of wastes cannot readily be dispersed into the atmosphere, a gas control system shall be provided.[25]

Upon closing a sanitary landfill, some regulations require seeding, contouring, and other reclamation-type work. The Wisconsin regulation authorizes the department to require installation of monitoring wells and water quality sampling and analysis after the site is closed.[26] The Model State Solid Waste Management and Resource Recovery Incentives Act of the Council of State Governments (1972) proposes a requirement that all persons operating under permit be required, upon completion of a sanitary landfill, to file a plat of the site with the county recorder, together with a description of the waste placed therein.

The Model Act contains some broader approaches to avoiding solid waste disposal problems by requiring that each municipality develop a solid waste management plan, by enabling inter-municipal cooperation in solid waste disposal, and by establishing tax incentives to encourage recycling in order to reduce the volume of solid waste.

Federal Guidelines

The Administrator of the U. S. Environmental Protection Agency has prepared Solid Waste Management Guidelines for the disposal of municipal waste under directive of the 1970 amendments to the Solid Waste Disposal Act of 1965 (Public Law 89-272). The guidelines represent the judgment of the EPA regarding what is necessary to assure both environmental protection and satisfactory and acceptable design and operation of land disposal facilities. They are intended to be achievable using current technology, while providing flexibility for unique and specific climatological, geological, geographical, and related conditions.

The guidelines are recommended for adoption by state and local governmental agencies; they are mandatory for federal agencies and for solid waste disposal on any federal lands.

The following is a brief description of the guidelines.

Selection of Wastes and Special Handling. The guidelines suggest consultation between responsible agencies, the designer, and the owner-operator as to what wastes will be accepted; and specification in the plans for procedures to be employed for wastes requiring special handling. They specify procedures for handling bulky wastes, dead animals, water treatment plant sludges, and incinerator and air pollution control residues (sludges and residues to be placed on the working face of the fill). The following wastes require specific approval of the agency:

Hazardous wastes (toxic, corrosive, infectious, explosive, etc.)
Infectious institutional wastes
Bulk liquids and semi-liquids
Sludges containing free moisture
Highly flammable or volatile substances
Raw animal manure
Septic tank pumpings
Raw sewage sludge
Certain industrial process wastes

Site Selection and Development. Site development plans should be prepared or approved by a professional engineer. They should include initial and final topographies at contours of five feet or less; land use and zoning within a quarter mile of the site including locations of all buildings, roads, wells, watercourses, etc.; all airports within five miles (the site should not be located where the attraction of birds would pose a hazard to low-flying aricraft); projected use of the completed land disposal site (the guidelines indicate criteria for cultivation or structural use). Also to be performed are an evaluation of hydrogeology of the site to minimize impact on ground water resources, and evaluation of soil characteristics.

The guidelines state that "the location, design, construction, and operation of the land disposal site shall minimize environmental hazards and shall conform to the most stringent of applicable ground and surface water quality standards and requirements." They then specify that plans shall include current and projected use of water resources, in the potential zone of influence of the site; facts concerning water resources including initial quality; proposed location of observation wells; description of soil to a depth adequate to allow evaluation of water quality protection provided by it; provision for surface water runoff control; and potential of leachate generation and proposed control systems. If in a flood plain, the site should be protected against at least the 50 year design flood.

Surface watercourses and runoff are to be diverted from the site, by trenches, grading, and manner of construction. Leachate collection and treatment systems should be used where necessary.

Operation. The guidelines contain provisions concerning:

Dust and litter control
Open burning (prohibited)
Decomposition gases
Vectors (carrier capable of transmitting pathogens)
Aesthetics

Cover material

Compaction

Equipment

Safety

Records

B. Individual Sewage Systems (septic tanks)

While prevention of ground water pollution is a major purpose of solid waste disposal regulations, it has not been a major purpose in the regulation of individual sewage systems such as septic tanks. The latter regulations are directed primarily at protecting the health of the septic tank user and his near neighbors.

The "Manual of Septic Tank Practice" of the U. S. Department of Health, Education, and Welfare, generally followed by states in the adoption of septic tank regulations, illustrates this emphasis in setting out the objectives of septic tank regulations in its suggested ordinance.[27] Such regulations are to establish minimum standards that will insure that the wastes discharged:

1. Do not contaminate any drinking water supply.
2. Are not accessible to insects, rodents, or other possible carriers of disease which may come into contact with food or drinking water.
3. Do not pollute or contaminate the waters of any bathing beach, shellfish breeding grounds, or stream used for public or domestic water supply purposes or for recreational purposes.

4. Are not a health hazard by being accessible to children.
5. Do not give rise to a nuisance due to odor or unsightly appearance.
6. Will not violate any other laws or regulations governing water pollution or sewage disposal.

Statutory authority for control of septic tanks is usually contained in some basic authority of a state agency. Their control is specified in regulations. Administration is primarily through local health officers, with state supervision.

Typically, regulations contain the following elements:

1. A requirement that the owner obtain a permit. (In Wisconsin, one must have a permit in order to purchase a septic tank; sale to any person who has no permit is also prohibited.[28] In Ohio, one cannot sell lots in a subdivision until he has approval of plans showing that septic tank regulations can be met.[29] In Vermont, one must have a permit from the Agency of Environmental Conservation prior to subdividing the land.[30])
2. A condition that a permit will not be issued if the landowner could feasibly tap into a public sewer.
3. Requirements that the landowner furnish a soil report and results of a percolation test. The regulations vary as to assurances that these tests are thorough and that they are competently conducted.

4. Minimum lot size, maximum slope.
5. Specification of capacity of equipment and minimum total linear feet of leaching tile for installation in particular types of soil, for the various quantities of waste anticipated. Other constraints applied are lot size, ground slope, percolation rate, soil type and depth, and depth to ground water.
6. Submission of a detailed plan of the septic tank (or other system) design and proposed location of the tank and leaching beds, location of structures, property lines, water resources, and water lines and wells. A legal description of the property may also be required.
7. Equipment specifications, such as construction of the tank, size and length of tile in leaching beds, and method of installation.
8. Installation requirements concerning distance to water or bedrock, distance from wells and water resources, bedding, backfill, etc.
9. A requirement that abandoned septic tanks be filled with earth and covered.
10. A requirement that inspection be allowed.

The regulation also may specify requirements for constructing and locating cesspools or privies (some states prohibit these devices), and for aerobic treatment systems and sand filters. The Maryland regulation contains specifications for deep seepage pits, which some states prohibit.[31] The regulations for private sewage disposal may also include regulations for holding tanks and chemical toilets.

Some prohibitions found in private sewage disposal regulations are that such devices may not:

1. Cause a nuisance;
2. Discharge into wells, sink holes, onto the ground, or into surface drainage courses;
3. Discharge off the lot upon which it is located (except under special conditions);
4. Be located in a flood plain;
5. Be constructed or situated so that "clear" water may drain into the septic system -- i.e., roof drainage, other non-sewage sources.

Wisconsin allows denial of a permit simply on the basis of soil type, "when a property consists entirely of soils having a very severe limitation for on-site liquid waste disposal".[32] The applicant may, however, using results of percolation tests and other data, offer evidence to support his application. The proposed Maine regulation (June 17, 1974) eliminates the percolation test, permitting or denying any particular type or size of system on the basis of soil groups and bedrock and ground water conditions.[33]

The California Regional Water Quality Control Board, Central Valley Region, in its "Guidelines for Waste Disposal From Land Developments", after stating certain minimum criteria for allowing use of a septic tank, uses a "point system" which it describes as follows:[34]

> A number of factors affect the capability of individual septic tank - leaching systems to provide safe continuous disposal of wastes. Those factors which come within the purview of the Board, in that the Board may specify conditions or areas where the discharge of waste will not be permitted, are soil absorption capability, soil depth, depth to ground water, and slope.
>
> Any of these factors may in itself limit the system capability; however, the general case is that system capability is affected by all factors acting simultaneously. The preceding minimum criteria establish conditions which will eliminate undue influence of a single factor upon system reliability but do not recognize the interplay among all factors. Compliance with only minimum criteria, therefore, will not necessarily result in an acceptable system.
>
> The following procedure has been formulated to recognize the interplay among the factors listed above. The procedure utilizes the minimum criteria contained herein as a base, and credits those factors which are in excess of the minimum criteria. Compliance with the following point system should minimize problems which occur due to concentrating large quantities of waste in limited areas.
>
> Point allowances are calculated for each factor. The sum of the

point allowances establishes the suitability of the system. A suitable disposal area for a septic tank - leaching system from a single family residence must total a minimum of 45 points.

I. Soil Absorption Capacity

Percolation Rate (minutes per inch)	Minimum Usable Disposal Area (ft^2)	Point Allowance for Expansion Area
41-60	12,000	2/1,000 ft^2 over 12,000 ft^2
21-40	10,000	2/1,000 ft^2 over 10,000 ft^2
11-20	8,000	2/1,000 ft^2 over 8,000 ft^2
Less than 10	6,000	2/1,000 ft^2 over 6,000 ft^2

II. Depth of Soil or Ground Water, Whichever is More Restrictive

Depth in Feet*	Point Allowance
5-10	5
11-15	15
16-20	20
Greater than 20	25

III. Slope in Disposal Area

Slope, %	Point Allowance
21-30	0
11-20	15
10 or Less	30

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*Depth below the bottom of the leaching trench or seepage pit to water, rock or first impervious layer.

An additional dimension in septic tank control is provided by the Pennsylvania Sewage Facilities Act which requires that each municipality prepare a detailed plan for waste disposal, then requires denial of a permit for installation of a septic tank if the installation is not consistent with the plan.[35] The Act requires that permits be issued by state certified municipal sewage enforcement officers who pass a rigorous training course and test.

Still another dimension may be seen in a regulation such as Ohio's which requires that septic tank installers and sewage tank cleaners be registered.[36] Registrations may be revoked for violation of septic tank regulations.

Some regulations are directed at maintenance and at sludge disposal. A number of states specifically allow revocation of a permit if the system does not perform according to requirements. The Wisconsin regulation contains a requirement that a septic tank be cleaned whenever sludge or scum occupies one-third of the tank volume.[37] The statute then specifies that sludge may be disposed of in a public sewer, an approved site, by burial on the premises on which produced under certain conditions, or by spreading on land not used for pasturing livestock or growing vegetables. Maine has adopted guidelines for septic tank sludge disposal on land, covering the following alternatives:

Total recycling of nutrients through green manure crops in a conservation rotation;

Disposing of septic tank sludge on the land by spreading;

Lagoon treatment and liquid disposal;

Disposal by spray irrigation;

Dewatered sludge disposal.[38]

The Oregon regulation prohibits spreading of septic tank sludge on land without approval of the state or local health agency having jurisdiction, and in any case prohibits its use as fertilizer on root crops, vegetables, low-growing berries, or fruits that may be eaten raw; and use on grass in public parks or other areas in a way that persons could unknowingly come in contact with it.[39] That regulation contains specifications for sludge lagoons and sludge spreading areas.

Another approach to prevention of water pollution from septic tank use is limitation of materials placed in them. Prohibition of use of certain types of household water-softening units has been suggested. In Suffolk County, New York, an ordinance was passed prohibiting the sale of certain types of laundry and dishwashing detergents.[40]

C. Animal Feedlots

Animal feedlots are "concentration animal feeding operations" under Section 502(14) of the Federal Water Pollution Control Act Amendments of 1972, and thus may be required to have a permit as a "point source" under the National Pollutant Discharge Elimination System. The EPA Administrator under his authority to use discretion has limited this requirement to large operations. Feeding operations consisting of the following number of animals, or smaller, are excluded, although such an operation may be required to obtain a permit if it is in fact a significant source of pollution:

1,000	slaughter steers and heifers
700	mature dairy cattle
2,500	swine weighing over 55 pounds
10,000	sheep
55,000	turkeys
100,000	laying hens and broilers if the facility has continuous flow watering
30,000	laying hens and broilers if the facility has a liquid manure handling system
5,000	ducks[41]

State animal feedlot regulations apply both to the larger lots to which the NPDES requirements apply, and to the smaller lots that do not come within that system.

State animal feedlot regulations typically apply to the situation where the ratio of the number of animals to land area is so high that concentrations of waste threaten to cause water pollution. They require a permit and certain information for obtaining a permit. Basically, the regulations require that water be diverted above the lot, and that below the lot a settling pond and lagoon be provided, with additional treatment if necessary. Some also specify the manner in which waste from the lot may be stored or disposed of on land. The regulations vary in detail. Montana's regulation is brief, and general in statement.[42] The Iowa[43] and Oregon[44] regulations are relatively detailed.

The Model State Confined Animal Feeding Environmental Control Act suggested by the Council of State Governments (1973) contains definitions, permit authority and procedures, right to enter and inspect, authority to adopt regulations, and provisions for enforcement, penalties, and appeal. The substantive proposals are contained in two Annexes, one covering Criteria for Permit Application and Issuance, the other covering Guidelines for Standards Criteria for the Design, Construction, and Management of Confined Animal Feeding and Holding Facilities.

Operations Subject to Regulation. The Iowa confined feeding regulation includes an open feedlot only where the animal population exceeds a specified number and the square feet of lot area per animal is less than a specified number. For instance, the regulation applies to beef cattle where animal population exceeds 100 and lot area per animal is less than 600 square feet. For sheep, the figures are 1,200 population and 60 square feet. The Iowa regulation separately treats a "confinement feeding operation" -- one having a roofed or partially roofed enclosure where wastes are removed as liquid or semi-liquid. In such a case, area is not involved and the regulation applies by number of animals -- e.g., for beef cattle, 50; for sheep, 600.

Registration of an open feedlot is required if one or more of the following conditions exist:

1. The number of animals exceeds (beef cattle: 1,000);
2. The feedlot contributes to a watercourse draining more than 3,200 acres of land above the lot and the distance from the feedlot to the nearest point on the watercourse is less than (beef cattle: 200 feet per 100 animals);
3. The runoff water from the feedlot (or collection facility) flows directly into a tile line or other buried conduit, well, hole, pit, lake or pond.

Registration of a "confinement feeding operation" is required if:

1. The number of animals exceeds (beef cattle: 100);
2. Overflow contributes to a watercourse;
3. The runoff water from the feedlot (or collection facility) flows directly into a tile line or other buried conduit, well, hole, pit, lake or pond.

Other states: Kansas -- 300 or more head of cattle, swine, sheep, or horses, any operation using a lagoon, or any operation having a water pollution potential;[45] Minnesota,[46] Montana,[47] Nebraska[48] -- feeding any livestock in a confined area not normally used for raising crops or as pasture; Oregon -- feeding or holding areas in buildings, pens, or lots where the surface has been prepared with concrete, rock, or fibrous material to support animals in wet weather or where the concentration of animals has destroyed the vegetative cover and the natural infiltrative capacity of the soil.[49]

The Model Act requires a permit for any confined feeding facility upon which ____ animal units are confined for more than 30 days in a calendar year, and to any confined feeding area which violates a law or regulation. An Annex to the Act suggests relative animal unit numbers based on Biochemical Oxygen Demand (in which the beef cattle number is 1, feeder pigs 35, laying hens 180, etc.). The law is applicable to feeding or holding animals in enclosures that are less in area than is necessary for the soil assimilation of animal wastes generated on the land without violating any law or regulation (e.g., water pollution control laws). The agency is directed to adopt regulations specifying areas to be included in terms of quantitative animal densities relative to land area.

The Iowa regulation and an Annex to the Model Act contain factors to be considered in determining whether a facility will constitute a pollution problem, such as location relative to other water, type of surface, soil and slope, hydrological and geological conditions, permeability of retention structure to excessive seepage, control of discharge in proportion to stream flow, animal density, anticipated waste load, distance to structures occupied by humans, direction of prevailing winds, applicable water quality standards, and factors concerning waste disposal. Despite other criteria in the law or regulations, the law will be applied or waived in a particular situation depending upon these factors.

Information Required for a Permit. Iowa requires the location to be sketched on an aerial photograph, to include:

Building and lot areas

Lagoons or waste holding pits

Direction of surface drainage from site

Location of wells and dwellings within 1,000 feet of site

Adjacent land owned

Land area set aside for waste disposal

Minnesota and Oregon have similar requirements, but Minnesota also requires a description of geologic conditions, soil types, and ground water elevations, a plan of operational procedures, location of treatment works, and quantity and type of effluent to be discharged; Oregon requires climatological data and details of feed preparation and handling, and a location map showing ownership, zoning, and use of adjacent lands and location of the proposed operation in relation to residences and domestic water supply sources.

Prohibited Locations

The Nebraska regulation prohibits location of a livestock waste control facility (e.g., a detention pond) within 100 feet of any well used for domestic purposes, or within 1,000 feet of a municipal water supply well unless the operator can show that it will not result in ground water pollution.

Minnesota prohibits location of new livestock feedlots within shoreland or a floodway (protected under other statutes), within 1,000 feet of a public park, in sinkholes or areas draining into sinkholes, or within one-half mile of the nearest point to a concentration of ten or more private residences.

An Annex to the Model Act suggests prohibition of confined feeding facilities within 500 feet from waters edge, within a floodplain, within 1,000 feet of public property, or within 1,000 feet of an accumulation of ten or more private residences.

Facility Requirements

Subject to waiver when not necessary, or additional requirements when necessary, the Iowa regulation specifies that the minimum water pollution control facilities for an open feedlot shall be terraces or retention basins capable of containing four inches of runoff. Diversion of surface drainage above the feedlot is required. A settling basin is to be provided where necessary. For a "confinement feeding operation", the minimum facility is a tank or basin capable of holding 120 days' waste.

The Kansas regulation works in a similar manner, requiring facilities if a potential water pollution problem exists. For cattle, the retention pond must hold three inches of runoff.

The Nebraska regulation requires a detention structure capable of holding runoff from a ten year, 24-hour storm. For "housed" operations, the requirement, as in Iowa, is the capacity to hold 120 days' accumulation.

The Oregon regulation is considerably more detailed, consisting not only of capacity requirements, but method of diking, requirement of overflow relief structures, prevention of erosion, and other regulations including solids handling systems and conveyance and disposal facilities.

An Annex to the Model Act suggests design of holding structures on the basis of peak runoff from a ten-year frequency, 24-hour duration storm.

Operation of Facilities

The regulations also contain certain operating requirements, which in essence require that water pollution be prevented. Montana requires that the operator provide personnel with adequate skill and time to maintain and operate the facility consistent with the approved application. The Nebraska regulation states: "Caution should be exercised to insure that a thin layer of manure remain on the lots during scraping and that the soil manure interface not be disturbed." That regulation also instructs the operator in keeping the feedlot surface aerobic so that production of odors is curtailed. The California Water Resources Board has issued guidelines specifically addressed to the protection of ground water; among these is the recommendation that salt in animal rations be limited to that required to maintain animal health and optimum production.[50]

Storage, Transportation, and Disposal

The regulations also may apply to storage, transportation, and disposal of collected wastes. In essence, the regulations state that these activities shall be conducted so that water pollution does not occur, and pollution control laws are complied with.

The Oregon regulation contains requirements for liquid manure spreading, including requirements for: a plan of uniform coverage, plan of rotation for liquid manure irrigation systems, selection of equipment, provision of adequate land for year-round disposal, type of land to use, harvesting of vegetative cover, livestock grazing, and prohibition of seepage basins except where the operator can demonstrate that ground water pollution will not result.

The Iowa Water Quality Commission has adopted a policy on land disposal of animal wastes, concerning maximum average nitrogen application rate (250 pounds per acre), phosphorus limits, waste disposal on snow-covered land, on land subject to flooding, and on land near watercourses, and odor control.

An Annex to the Model Act emphasizes the need for systematic removal of wastes from holding structures, and for proper storage and disposal of such wastes. It describes practices to be followed in storing, transporting, and disposing of wastes.

D. Deep Well Disposal of Wastes

States have enacted statutes and have adopted regulations specially directed at the disposal of wastes in deep formations where such wastes will be permanently isolated from contact with fresh water resources and from human activity. Some states specifically prohibit the practice. State water pollution control laws that apply to ground water may also, by their general provisions, prohibit the practice without a permit where the disposal would affect a water resource.

The federal Safe Drinking Water Act of 1974 (Public Law 93-523) requires states to adopt programs prohibiting underground injection without a permit, and requires the federal EPA to adopt regulations for state underground injection control programs, to ensure that such injection will not endanger drinking water sources. The federal regulations had not yet been adopted as the present manual was written. In emergencies, the law authorizes the EPA to take such actions as the Administrator may deem necessary to protect the health of persons if a contaminant is likely to enter a public water supply system from any source.

Since enactment of the Federal Water Pollution Control Act Amendments of 1972, states have been under the constraint of Section 402(b) of that act which makes approval by the EPA Administrator of a state's water pollution control law under the NPDES program conditional upon a finding by him that adequate authority exists in the state to "control the disposal of pollutants into wells". The EPA Administrator by

Decision Statement No. 5 (April 2, 1974) adopted a policy statement on Subsurface Emplacement of Fluids, the goals of which are stated to be to protect the subsurface from pollution, ensure that engineering and geological safeguards are adequate to protect the integrity of the subsurface environment and are adhered to, and to encourage development of alternative means of disposal which afford greater environmental protection. To accomplish these goals, the Administrator declared his policy to be as follows:

1. The EPA will oppose emplacement of materials by subsurface injection without strict controls and a clear demonstration that such emplacement will not interfere with present or potential use of the subsurface environment, contaminate ground water resources or otherwise damage the environment.
2. All proposals for subsurface injection should be critically evaluated to determine that:
    a. All reasonable alternative measures have been explored and found less satisfactory in terms of environmental protection;
    b. Adequate preinjection tests have been made for predicting the fate of materials injected;
    c. There is conclusive technical evidence to demonstrate that such injection will not interfere with present or potential use of water resources nor result in other environmental hazards;
    d. The subsurface injection system has been designed

and constructed to provide maximal environmental protection;

   e. Provisions have been made for monitoring both the injection operation and the resulting effects on the environment;

   f. Contingency plans that will obviate any environmental degradation have been prepared to cope with all well shut-ins or any well failures;

   g. Provision will be made for supervised plugging of injection wells when abandoned and for monitoring to ensure continuing environmental protection.

3. Where subsurface injection is practiced for waste disposal, it will be recognized as a temporary means of disposal until new technology becomes available enabling more assured environmental protection.

4. Where subsurface injection is practiced for underground storage or for recycling of natural fluids, it will be recognized that such practice will cease or be modified when a hazard to natural resources or the environment appears imminent.

5. The EPA will apply this policy to the extent of its authorities in conducting all program activities, including regulatory activities, research and development, technical assistance to the States, and the administration of the construction grants, State program grants, and basin planning grants programs and control of pollution at Federal facilities in accordance with Executive Order 11752.

Elements meeting the requirements of the policy statement may be seen in a number of state laws and regulations on this subject. Some states have met the requirements without specific provisions, by setting requirements administratively on a case-by-case basis under general statutory authority (e.g., Texas, Ohio).

Statutes and regulations include definitions, permit requirements, information and pre-testing requirements, standards for allowing injection, logging, monitoring, and reporting requirements, financial responsibility requirements (Michigan requires a $15,000 bond),[51] and requirements concerning casing, back-up facilities, operation, and abandonment.

Waste well disposal regulatory provisions are often closely associated with, or a part of, oil and gas well regulatory requirements. Some of the statutes are directed only at protection of water resources; others specify water resources and oil and gas, other resources, or public health. Multiple approvals are sometimes required, as in Kansas where the State Corporation Commission gives approval concerning oil and gas protection, and the Department of Health gives approval concerning water resources. In Ohio, the Division of Oil and Gas may disapprove a permit application if the proposed injection would present an unreasonable risk that waste or contamination of oil or gas in the earth will occur; the Division of Geological Survey may disapprove if an unreasonable risk of loss or damage to valuable mineral resources would occur; and the Environmental Protection Agency may disapprove if the proposed injection would cause water pollution.[52] In addition, the permit may be conditioned to protect health, safety, or the conservation of natural resources.

Alternative Measures

A prohibition against deep well disposal if alternative methods are feasible may be contained in a regulation (e.g., Oklahoma),[53] but more often it is implemented in administrative policy. Kansas, for example, adopted the following policy in 1970:

> The use of industrial waste disposal wells will be considered only for those wastes that cannot be treated and disposed of by other methods. On this basis, we will require that each application for the disposal of substances other than salt water be accompanied by a report giving the results of studies of alternate methods of waste disposal and a justification of why subsurface disposal is considered the least hazardous method so far as environmental protection is concerned.

Information

Accompanying the EPA Administrator's Decision Statement No. 5 was a statement of parameters describing the information that should be provided by the injector. These include requirements for considerable detail as to location of the proposed well and other features around it, property ownership, wells (including statement of deepest formation penetrated within twice the calculated zone of influence of the proposed well), maps of water supplies, mineral resources, and geologic structure, description of fluids to be injected, potentiometric maps, volume, rate, and injection pressure of the fluids, detailed information on geological and physical characteristics of the injection interval and confining beds, and engineering data describing the proposed well, casing, installation, testing, logging, injection procedure, monitoring, and contingency plans. The Administrator's statement advises:

> Preparation of a report thoroughly investigating the effects of the proposed subsurface injection well should be a prerequisite for evaluation of the project. Such a statement should include a thorough assessment of: (1) the alternative disposal schemes in terms of maximum environmental protection; (2) projection of fluid pressure response with time both in the injection zones and overlying formations, with particular attention to aquifers which may be used for fresh water supplies in the future; and (3) problems associated with possible chemical interactions between injected wastes, formation fluids, and mineralogical constituents.

The statement advises an injector to contact the regulating agency to determine what will be required, stating that the agency will specify the exact data requirements on a case-by-case basis.

Nebraska and Colorado require a legal description of the area within a radius of two miles, and a map including the same area showing surface and mineral ownership, water and oil wells, mines, and test holes.[54] These states also require:

> A description of local topography, industry, agriculture, popu-

lation densities, culture, wildlife, and fish and other aquatic life within the area of the proposed system with a projection as to the probable effects of the system upon industry, agriculture, population, culture, wildlife, and fish and other aquatic life.

These and other state regulations also contain many of the requirements contained in the Administrator's statement. The Nebraska regulation requires an evaluation of geologic and hydrologic conditions that demonstrate:

Geologic:

a. The disposal well shall be located in an area known to contain geologic structures capable of containing the proposed injected effluent.

b. The injection zone shall have sufficient porosity, permeability, thickness, structural configuration, and areal extent to act as a safe storage reservoir.

c. The injection zone shall be isolated vertically by formations that are, for practical purposes, impervious to the effluent.

d. The injection zone should not contain natural resources in the same geologic structure which may be affected by said injection.

Hydrologic:

a. The injection zone should contain interstitial water having a concentration of at least 5,000 milligrams per liter total dissolved solids.

b. The rate and direction of ground water movement in the injection zone should be evaluated.

c. If the injection zone is known to contain ground water subject to protection in other areas, the direction and distances from the injection well to the brackish water or saline water interface shall be estimated within reasonable limits.

d. An estimation of the fluid chemistry of the interstitial water in the injection zone shall be made.

The regulation also requires an evaluation of the injection zone for porosity, permeability, chemical constituents of interstitial waters and the chemical and physical characteristics of the injection zone rocks, temperature of the injection zone, static-bottom-hole pressure, permeable thickness of the injection zone, and injection profile. The applicant must also demonstrate that the proposed effluent is compatible with the injection zone and its interstitial water and that no undesirable chemical or physical reaction will occur.

Design of Well

The Texas Water Quality Board states: "The type of construction for injection wells is quite variable because of the different compositions and volumes of waste injected. The Board has not adopted standards on well construction, but prefers to consider each proposal on an individual basis."[55]

The Nebraska regulation is detailed, but it specifies that design must be "within but not limited to" its specifications. These include casing requirements, safety factors for collapse, tension, and internal pressure, cementing procedures, logging, transport of effluent to the well by injection tubing, manner of fixing the injection tubing, safety-valve requirements, and surface equipment design. The regulation requires surface equipment shall be designed so that the system can be safely shut down in the event of component failure, and that a secondary facility be maintained in the event of a temporary well failure. The latter may consist of a lined, impermeable retention pond or a treatment process.

Some states rely upon provisions in their oil and gas drilling laws and regulations for basic regulation of disposal well design, construction, and operation, and enforcement of regulations, but require specific practices on a case-by-case basis.

Other Regulations

Other regulations include those for pre-testing the well, monitoring and reporting, operation practices, and requirements for abandonment. The Michigan regulations are detailed in these respects.[56] Michigan requires at least one observation well within 100 feet of the disposal well for each well used for disposal of radioactive materials. The Michigan regulation also requires performance testing of each disposal well at least once each calendar quarter.

Some states limit permit duration (e.g., Oklahoma, five years). The EPA Administrator in his Decision Statement No. 5 indicated that the meaning of his statement that subsurface injection will be recognized as a "temporary means of disposal" was that it would be approved only for the life of an issued permit, and that should more environmentally-accepted disposal technology become available, a change to such technology would be required.

Regulatory Proposals

The Council of State Governments suggested a Model State Toxic Waste Disposal Act in 1973. By definition, it would apply to:

> any substance or combination of substances which, in the judgement of the director, consistent with any applicable federal law, may pose a substantial present or potential hazard to human health because such substances are non-degradable or persistent in nature, or because they can be biologically magnified, or because they can be lethal, or because they otherwise cause or tend to cause detrimental cumulative effects.

Under present state regulations, wastes that may be injected vary, but by definition some could include any type of waste whether hazardous or not, including sewage. In practice, the states limit waste types by following a policy of allowing disposal only if there is no feasible alternative. The Model Act provision makes the limitation explicit.

The Model Act provides for a State Toxic Waste Disposal Plan, to include regulations, classifications by type of waste and disposal locations and procedure, and guidelines for procedures, standards, and for the distribution and proximity of disposal or storage sites in specified geographic areas and types of geologic formations. Any disposal project would have to be consistent with this State Plan.

The Model Act requires compliance with the law and regulations and certain approvals of the director; monitoring and reporting; inspection and entry by the director or his representatives; and public access to information. It contains provisions concerning emergency orders, financial responsibility of the operator, and enforcement. An Annex contains suggested information requirements similar to those discussed in the foregoing material.

The Ohio River Valley Water Sanitation Commission (ORSANCO) in 1973 adopted "Recommendations for the conduct of regulatory actions including the scope and sequence of administrative procedures and the evaluation of geological and technological factors."[57] It identified seven steps as essential in the administration of a state program. Briefly, these are:

1. Preliminary assessment by the applicant of the geology and geohydrology;
2. Application to the state agency to drill and test a well, with supporting documents;
3. Drilling and evaluation of the well;

4. Request by the applicant for approval to inject waste water;
5. Evaluation of the proposal by the state agency;
6. Issuance of instructions for operation; and
7. Procedures for abandonment.

Where the system is to be located within five miles of a state border, the appropriate agency in the adjoining state is to be given an opportunity to review and comment on the application.

The ORSANCO proposal contains suggested forms, and an outline of scope and content of a feasibility report.

E. Other Well Disposal of Wastes

Many states, even among those which allow deep-well disposal, prohibit other disposal of wastes in wells. Others allow it under permit, either specially or as a point source under an NPDES or similar system. Washington's regulation, for instance, states that the disposal of pollutants into wells, "excepting in the most extraordinary circumstances", is not authorized. If a permit is issued, it must include terms and conditions to control the disposal in order to prevent pollution of ground- and surface-water resources and protect the public health.[58]

Florida has a specific regulation controlling drainage wells, requiring certain data for application, including bacteriological examination of water from all water supply wells within one-mile radius that are drilled to the approximate depth of the proposed drainage well. The regulation contains drilling requirements and other requirements concerning test wells and abandonment.[59]

California's Water Reclamation Law prohibits construction or use of a waste well extending into a waterbearing stratum suitable for use as a source of water supply for domestic purposes unless a Regional Water Quality Control Board finds that water quality considerations do not preclude it, and the State Department of Health, after a public hearing, finds that the proposed recharge will not impair the quality of water in the receiving aquifer as a source of domestic water supply.[60]

New York has adopted relatively detailed classes and standards for ground water which prohibit, for example, placement of raw or treated sewage, industrial wastes, etc., in the zone of aeration of "Class GA" waters which may impair the quality of the ground water to render them unsuitable for a potable water supply. This class includes fresh ground water best used as sources of potable water supply. The regulation contains schedules of standards including specific limits for physical and chemical characteristics.[61]

Control Point 4: MANAGEMENT OF WATER LEVEL AND PUMPING RATES

Most states have enacted statutes that determine the right to take water from lakes, rivers, streams, and underground sources. These statutes make it possible for public agencies to manage water levels and pumping rates, although the existence of a water-allocation statute does not necessarily signify that a state can "manage" its resource. The basic purpose of water-rights statutes is the same as with any property law -- security of interest. A state statute establishes an orderly system of water use, so that if one obtains a permit, he has some protection of his water source.

States that have no such statute rely upon the courts to determine water rights. Even states with water permit statutes have exempted certain uses, such as minimum quantities, or their statutes do not apply to certain waters or certain areas, and to this extent the common law still is the determinant of water rights in those states.

The Eastern states, some Midwestern states, and even some Western states follow "riparian" rules of water use insofar as the common law determines their water rights. Arid states follow "prior appropriation" rules of water use, but typically follow riparian principles where ground water is concerned. Essentially, the riparian law attaches water rights to the ownership of land abutting (or overlying) the water, requires that uses be reasonable, and does not assure a right to a definite supply. Appropriation law does not require ownership of land, establishes rights by priority in time, and assures a right to a definite supply, in perpetuity, except as shortages may cut off the right of appropriators who are junior in time.

In those states that follow riparian rules, two principal rules may be isolated as dividing the states into "absolute rule" and "reasonable use" categories.

Under the "absolute" or "English" rule, an owner of land may pump whatever water he can from the ground that he owns. If his pumping dries up that of a prior user, the prior user has no remedy. If his neighbor excavates for construction or mining purposes, cutting off the pumper's ground water supply, the pumper has no remedy. Each owner is said to have an "absolute" right to use his land in whatever way he desires. The principle is not quite that broad, however, since it is applied only to "percolating" waters and not to identifiable "underground streams". Also, a person may not injure his neighbor by digging or pumping that is malicious in intent.

Two policies underlie this rule: (1) the occurrence and behavior of ground water is not known, and thus a court should not attempt to adjudicate rights to it; and (2) protection of one person's right to a ground-water supply would prevent development by interfering with mining, building of roads, and other works.

A number of states follow this rule without statutory control, including heavily-populated industrial states such as Pennsylvania, Ohio, Illinois, and Texas.

The "reasonable use" or "American" rule is a modification of the "absolute" rule. Under this rule, the owner of land may be restricted to the amount of water he needs to reasonably benefit his land. New York, Michigan, and Missouri, for example, are classified as "reasonable use" states.

A variation of the "reasonable use" rule is the "correlative rights" rule. While under the former rule, when a shortage occurs the law does not allocate available water, under the "correlative rights" rule it does. Landowners are limited to amounts equal in proportion to the proportionate area of land over the water supply concerned. This designation is applied to a line of California cases.

Permit Systems

When states have adopted permit systems of water allocation, whether surface or ground water, they have in effect adopted the Western principle of "prior appropriation". This principle minimizes state involvement by requiring essentially factual determinations, namely, of who began using the water, in what quantity, and of how much water the source will yeild. When permits have been issued to the extent that the source will yeild water, no more permits are issued.

The statutes contain numerous variations on this basic principle, as can be seen in the following material describing some of the major features of state water-permit statutes.

Coverage. All but a few statutes apply to both surface and ground water. A number apply to ground water only, others to surface water only.

A minority of states with permit statutes limit controls authorized by the statute to those areas designated as critical, or otherwise especially requiring control. Examples of criteria for designation of such areas are:

Arizona: an area not having sufficient ground water to provide a reasonably safe supply for the irrigation of cultivated lands located within the basin at the then current rates of withdrawal.[62]

Montana: withdrawals are, or are likely to be, in excess of recharge or significant disputes regarding priorities and amounts of use exist.[63]

Oregon:
(1) water levels are declining excessively;
(2) substantial interference is developing between users;
(3) the ground water supply in the area is being overdrawn;
(4) the water quality is deteriorating;
(5) there is no "unappropriated" water in the ground water reservoir.[64]

New Jersey: diversion of ground water exceeds or threatens to exceed, or otherwise threatens or impairs, the natural replenishment of such waters.[65]

North Carolina: uses of water
(1) have developed or threatened to develop to a degree which requires coordination and regulation or
(2) exceed or threaten to exceed, or otherwise threaten to impair, renewal or replenishment of such waters.[66]

Exemptions from the requirement that a permit be obtained can also greatly affect the coverage of a law. For instance, Western statutes almost universally exempt uses in existence at the time of enactment. Some Eastern statutes do not. Almost all states exempt domestic uses -- the superior right under the riparian law -- either specifically or by use of a quantity exemption large enough to allow domestic use without regulation. A common practice is to exempt uses less than 100,000 gallons per day. Iowa uses a 5,000-gallon-a-day limit;[67] some states make no exemption by amount. A common exemption is for agricultural uses, even to include irrigation. Some states exempt nonconsumptive uses, or require that a permit be issued for such uses without further showing.

Criteria for Issuing a Permit. Every statute contains some specification of the nature and effect of use that must be shown in order for a permit to issue. The most common of these specifications is that the use be "beneficial". This is one of the requirements of the Western case law, where it meant that the use could not be wasteful or detrimental. Iowa, a state that follows the riparian law, when it adopted a permit system in 1957, added this requirement to its law in the following language:

> "Beneficial use" means the application of water to a useful purpose that inures to the benefit of the water user and subject to his dominion and control but does not include the waste or pollution of water.[68]

The Minnesota statute gives a list of "beneficial public purposes" which are given as examples but which do not limit the meaning of the term:[69]

a. Water supply for municipal, industrial, agricultural, or other purposes;
b. Recharge of underground water strata;
c. Retention of water to prevent or reduce downstream flooding, thereby minimizing erosion and resultant property damage;
d. Entrapment and retention of nutrients and other materials which impair the quality of natural resources;
e. Recreational activities such as swimming, boating, fishing, and hunting;
f. Public navigation other than for recreational purposes;
g. Wildlife habitat such as fish spawning and rearing areas, waterfowl nesting and feeding areas, and areas for the rearing, feeding, and protection of other wildlife;
h. Areas designated as scientific and natural areas.

Maryland expresses this in the obverse, by denying a permit for a use that is inadequate, wasteful, dangerous, impracticable, or detrimental to the public interest.[70]

Florida has improved upon the requirement, by requiring that a use be "reasonable-beneficial".[71] California requires this standard by its constitution.[72]

Another common requirement in the statutes, which derived from the Western law of prior appropriation, is that the use be "in the public interest". The statutes make various interpretations. In Kansas, the chief engineer, in determining whether an application will adversely affect the public interest, is to:

> take into consideration the area, safe yield and recharge rate of the appropriate water supply, the priority of existing claims of all persons to use the water of the appropriate water supply, the amount of each such claim to use water from the appropriate water supply, and all other matters pertaining to such question.[73]

Alaska requires:

> In determining the public interest, the Commissioner shall consider:
>
> 1. the benefit to the applicant resulting from the proposed appropriation;
> 2. the effect of the economic activity resulting from the proposed appropriation;
> 3. the effect on fish and game resources and on public recreational opportunities;
> 4. the effect on public health;
> 5. the effect of loss of alternate uses of water that might be made within a reasonable time if not precluded or hindered by the proposed appropriation;
> 6. harm to other persons resulting from the proposed appropriation;

7. the intent and ability of the applicant to complete the appropriation; and
8. the effect upon access to navigable or public waters.[74]

Other statutory criteria for issuing a permit which bear on nature and effect of use include:

-- will not unduly affect those who already have permits. (or, there is unappropriated water available.)

-- the applicant's means of taking the water is adequate. (Idaho requires sufficient financial resources to complete the project.)[75]

-- not inconsistent with adopted water plans (Maryland, Iowa, Idaho, Florida.)

-- will not cause salt water intrusion or violate water quality standards (Maryland, New Jersey.)

-- reasonable, practical (Minnesota), necessary (New Jersey), equitable (Delaware,[76] New Jersey)

Maryland requires that a permit be issued if the proposed use is the greatest practicable utilization of the water resource. North Carolina, South Carolina,[77] and Georgia[78] have similar laws which state that the agency must issue a permit for nonconsumptive uses; where the use is consumptive, the agency must deny it if its effect would be "contrary to the public interest". The statute then directs the agency to consider numerous factors in adopting regulations and in issuing permits, including:

- The number of persons using an aquifer or stream and the object, extent and necessity of their respective withdrawals or uses;
- Nature and size of the stream or aquifer;
- The nature of any impairment of the aquifer or stream;
- The injury to public health, safety or welfare which would result if such impairment were not prevented or abated;
- The kinds of businesses or activities to which the various uses are related;
- The importance and necessity of the uses claimed, the extent of any injury or detriment expected to be caused to other water uses; and
- Reduction of flows in other watercourses or aquifers.

Another type of criterion for issuing a permit is the priority or preference. The most common, either express or implied, is "first in time, first in right". Examples of other priorities are public use (Alaska, Arizona), domestic use (Colorado[79]), most beneficial use (Alaska), and uses designated by the Department of Natural Resources as "undesirable" or "preferred" (Florida). The Florida statute also instructs the administering agency, in cases of competition, to choose those which "best serve public interest". Arizona, when there are two or more conflicting applications for the use of available water, gives preference in the following order:

1. Domestic and municipal uses;
2. Irrigation and stock watering;
3. Power and mining uses; and

4. Recreation and wildlife, including fish.

Duration of Right. Western states in enacting statutes adopted the rule of their common law that a right can be extinguished by non-user or waste. Eastern states have also adopted this rule, but many have also set a limit, typically ten years, on the life of a permit. In some states the user must then reapply as for a new permit.

Some statutes also allow cancellation of a permit for various reasons, such as violation of the law or a regulation. Some allow reduction in the quantity allowed to be taken by the permit, when it is found that part of the amount permitted is not needed by the user.

Other Provisions. Several of the states require the administering agency to protect minimum flow or other "in-stream" benefits in issuing permits; the Florida statute requires the Department of Natural Resources to give "careful consideration to the requirements of public recreation and the protection and procreation of fish and wildlife", and to prohibit inconsistent uses. Statutes commonly contain sufficient controls to limit use of an over-pumped aquifer, although statutes have been identified as lacking this authority (Arizona, Iowa). Statutes may also contain specific authority for control of water levels, or to control or carry out recharge operations.

One of the implied effects of all the statutes, to the extent that they set up a system which replaces the common law system of allocating water, is to do away with the riparian-law limitation that water belongs to the owner of riparian land, for use primarily upon that land, and in the case of surface water to be returned to the stream from which it came. With a view to possible constitutional objections, some states have included a declaration that waters of the state are public waters. Most states have also included a legislative finding of a problem, and a declaration of policy.

Common provisions give the agency power to investigate water resources, establish requirements for information in applying for a permit (or authorize the agency to adopt regulations to do this), require notice to affected persons and a hearing, provide appeal procedures for those denied a permit or affected by issuance of a permit, and provide for sanctions such as injunction and penalties. Penalties vary from state to state, but the more severe penalties for violation of the water-permit law authorize imprisonment for one year, and fines as high as $25,000 per day.

Usually, the permit-issuing agency has other functions affecting water management. Typically, these include water resource information-gathering and planning, and regulation of water-well drilling and construction, sometimes to include licensing of drillers. Another common activity of this agency is inspection and approval of dams and other water-control works. A few are given construction powers, including power to construct projects for water supply and flood control, for distribution of water, or for recharge of ground-water aquifers. The permit-issuing agency may also be the flood-control coordinating agency and the flood-plain regulatory agency, or it may also be the state's water-pollution-control agency.

Selected Statutes

Following are brief descriptions of the water-permit statutes of six states in various parts of the country -- New Mexico, Kansas, Iowa, Maryland, North Carolina, and Florida. They are presented here to illustrate types of systems and the manner in which the features discussed above fit into specific statutory procedures.

NEW MEXICO

New Mexico's permit system grew out of its prior-appropriation system of water rights. Under an earlier statute, one perfected a water right by first making use of the water, then filing a notice of this use. In 1907, the state enacted a law requiring a permit for use of surface water; its present ground-water statute was enacted in 1931.

The ground-water statute applies only to uses in areas in which the State Engineer has determined that the waters of an underground stream, channel, artesian basin, reservoir, or lake have "reasonably ascertainable boundaries".[80] As of 1973, he had declared 25 such areas covering more than a third of the state. In such an area, one must obtain a permit to use ground water. Also, a well driller to drill a well in such an area must be licensed by the State Engineer. Not subject to these requirements are domestic wells with casings not larger than 2 3/8 inches in diameter.

To approve an application, the State Engineer must find that there is unappropriated water in the designated ground-water source, that the proposed appropriation would not impair existing rights, and that it is a beneficial use. The Engineer may approve an application subject to conditions that he finds necessary to protect rights of others, both surface and underground.

A hearing is required for larger uses, at which anyone may protest who believes the granting of the permit will impair his water right. Applications for domestic and stock-watering purposes, and for non-commercial irrigation not to exceed one acre, are not subject to this procedure, but the State Engineer by rule limits such appropriations of water to three acre-feet annually.

A water-right holder loses his right if he fails to apply the water to a beneficial use for a four-year period and then continues to fail to use it for one year after notification and declaration of non-use by the State Engineer.

KANSAS

Ground water in Kansas belonged to the landowner under the "absolute rule" until enactment in 1945 of a statute converting the state's water rights law to an appropriation system.[81] To acquire a right to continued use, other than for domestic purposes, one must obtain a permit from the Chief Engineer of the Division of Water Resources of the Board of Agriculture. Riparian uses being made at the time of enactment of the statute were preserved, if the use was "beneficial".

An application for a permit must describe the nature and extent of the proposed appropriation in detail. The Chief Engineer is directed to approve the application if he finds that the proposed use is beneficial and will not impair use under an existing right or unreasonably affect the public interest. Guidelines given the Chief Engineer to determine "public interest" include factors of area, safe yield, recharge rate, and existing claims. The permit may contain conditions as necessary to protect the public interest.

In determining whether a proposed use will impair use under an existing right, the Chief Engineer is given a statutory definition of "impairment" which includes:

> The unreasonable raising or lowering of the static level or unreasonable increase or decrease of the streamflow or the unreasonable deterioration of the water quality at the water user's point of diversion beyond a reasonable economic limit.

Priority of right dates from the time of filing an application. Rights may be transferred, with or without a conveyance of land. One may lose his right if he fails to beneficially use his water for three successive years "without due and sufficient cause", and after he has been notified by the Chief Engineer and has had an opportunity to appear and show cause why his right should not be terminated.

The statute is specific in stating that a right to use of ground water does not give the applicant a right to the existing water level. It specifies that approval of each appropriation of ground water is subject to the express condition that such right must allow for a reasonable raising or lowering of the static water level, and that in determining what is reasonable, the Chief Engineer is to "consider the economics of diverting or pumping water for the water uses involved".

IOWA

Iowa, another riparian state, enacted a comprehensive statewide water-permit law in 1957.[82] The act exempts domestic uses, uses of less than 5,000 gallons per day, uses from rivers bordering the state, uses within the boundaries of a municipal corporation on May 17, 1957 (industrial users lose this exemption when their use increases by three per cent), and municipal uses until they increase their use in excess of 100,000 gallons or three per cent, whichever is greater, more than their highest per day beneficial use prior to May 16, 1957.

Permits are valid for ten years, but are renewed without hearing if no objection is filed.

A permit must be issued if it is found that the requested withdrawal is for a beneficial use and will not be detrimental to the public interests or to the interests of property owners with prior or superior rights who might be affected, and the use is found to be "compatible with the state comprehensive plan". Priority is accorded to applications in the order in which applications are received. The commissioner hearing the application is directed to use his judgement concerning the quantity of water for which a permit may be granted, but he is instructed by the statute that water for ordinary household purposes, for poultry, livestock, and domestic animals shall have priority over other uses. A person with an existing irrigation system in use prior to enactment of the statute must be issued a permit to continue unless some other riparian user is damaged thereby. The statute, declaring that "nothing in this chapter shall impair the vested right of any person", instructs the commissioner to follow the principles and policies of beneficial use declared by law. "Beneficial use" is defined as the application of water to a useful purpose that inures to the benefit of the water user and subject to his dominion and control, but does not include the waste or pollution of water.

A permit may not be issued that does not preserve the established minimum flow of a watercourse, that impairs the effect of the pollution-control laws, or that impairs the navigability of a navigable watercourse.

By regulation, use of water for irrigation of farm crops is limited to 18 inches per year, and for specialty crops to 36 inches per year. The amount for industrial use "shall be consistent with industry-wide usage for the same or similar purposes", and for municipal use not more than 200 gallons per day per capita; in both cases, however, the amount is to allow for growth where the need exists.

If a permittee ceased to use his permit for three consecutive years for the authorized purpose, his permit may be terminated. It may also be modified or cancelled upon breach of its terms and conditions, or for violation of the water-permit law, or in case the commissioner finds modification or cancellation necessary to protect the public health or safety or public interest in lands or waters, or to prevent substantial injury to persons or property. He may also suspend a permit in an emergency.

MARYLAND

Maryland was a pioneer among the Eastern "riparian" states in enacting a water permit statute in 1934. The statute applies to surface and ground water, statewide, but exempts domestic and farming uses, uses existing at the time of enactment, municipal uses in effect July 1, 1969, and rights granted by the General Assembly to the City of Baltimore.[83]

The Department of Natural Resources may reject a ground-water permit application if the proposed use:

- -- is inadequate, wasteful, dangerous, impracticable, or detrimental to the best public interest;
- -- would violate water-quality standards;
- -- would jeopardize the natural resources of the state.

A permit must be issued if:

> The plans of the applicant provide for the greatest practicable

utilization of the waters of the state and will adequately preserve public safety and will promote the general public welfare.

Permits are limited to ten years (or the time required to amortize investment), and renewal is the same as application for a new permit. The statute allows the Department to "correct" any permit where the total quantity permitted to be used is either not used or not needed.

Recently proposed regulations contain provisions for comprehensive control of Maryland ground-water resources. The regulations establish priorities, establish total average withdrawal limitations for particular areas, establish criteria upon which issuance of permits is based (including limitation of use according to amount of land owned by the applicant), regulates drilling and construction of wells, authorizes well-spacing requirements, and establishes three zones according to aquifer type and depth and requires use of such zones according to rate of withdrawal.

Priorities. The regulation states that when it becomes necessary to allocate water among competing uses whose total demand exceeds the dependable supply, the Administration shall give greater consideration to the needs of users in the following order:

1. Water supply for individual domestic and farm use, and municipal supplies which are publicly owned and operated;
2. Irrigation of crops used directly or indirectly for human consumption;

3. Industrial and commercial users who obtain ground water from privately owned wells and use it in their processing or distribute the water for sale;
4. Other, including irrigation of recreation areas, heating and air conditioning.

Another provision states that use of water by a private water company is not considered a beneficial use, and no new permit may be issued for that purpose except where a public agency cannot or will not provide the water.

Total Average Withdrawal Limitations. The regulations identify four areas east and west of the "fall line", according to non-carbonate rocks, carbonate rocks, unconfined aquifers, and confined aquifers, and state that average withdrawals of ground water may not exceed permissible yield judged by specified criteria based on stream flow, precipitation, or water levels.

Criteria for Issuance. The regulations state six criteria for issuance of a permit:

1. The State Ground Water Management Plan;
2. Amount of land owned by the applicant for which, or on which, the water is to be used;
3. Impact on ground water rights of other appropriators;
4. Ultimate recharge to aquifers based on precipitation (see below);

5. Reasonable needs of the applicant;
6. Satisfactory proof that issuance of the permit will not violate the State's Water Quality Standards or jeopardize its natural resources (e.g., will not cause intrusion of salt water).

The regulation states that maximum allowable pumpage for the consumptive use of ground water is limited to that quantity needed for reasonable use and will be allowed up to a yearly average for the daily pumpage of 780 gallons of water per acre of land owned if in accordance with the State Ground Water Management Plan. Withdrawal in excess of this amount may be allowed if it provides for the greatest feasible utilization of the waters of the state, adequately preserves public safety, and promotes the general public welfare. (The 780 gallon-per-acre figure is intended to approximate the "usable portion of precipitation that may eventually percolate into the ground".) Exception is made for public agencies if they compensate affected users.

The regulation also states that the Administration will consider water levels as a right in common among all appropriators. West of the fall line, declines up to permissible yield of a basin will be allowed (see "total average withdrawal limitations" above); east of the fall line, rights to water levels will be based on the management water levels established by the State Ground Water Management Plan.

The state may also, in order to provide for the optimum development of the ground water resource, control the number, location, spacing, depth, and construction of wells or well fields by the conditions placed upon the permit. The regulations contain detailed requirements for well construction permit issuance, reporting requirements, well construction standards (according to geologic areas), and testing.

Aquifer Management Areas. The regulation establishes three zones according to aquifer type and depth for confined aquifers of the Maryland Coastal Plain and requires that users of less than 10,000 gallons per day use a Zone I aquifer if available (aquifers with a transmissivity of less than 5,000 gallons per day per foot and a maximum depth to top of the aquifer of 300 feet below sea level); if not, then a Zone II aquifer (aquifers with a transmissivity of more than 5,000 gallons per day per foot and a maximum depth to the top of the aquifer of 300 feet below sea level). Users of more than 10,000 gallons per day must use a Zone II aquifer or a Zone III aquifer (aquifers with a depth of more than 300 feet to the top of the aquifer).

Ground water quality standards adopted by Maryland in 1973 describe three aquifer types based on transmissivity, permeability, and dissolved solids concentration, which are used to regulate discharge of water into ground water.

The regulation establishes quality standards to be maintained in each type of aquifer -- e.g., discharges into Type I aquifers may not exceed constituent limits under federal drinking water standards.

NORTH CAROLINA

North Carolina is one of the Eastern states that enacted a law to apply to areas delineated by a state agency. It applies to both surface and ground water, but exempts from permit requirements uses of 100,000 gallons per day and smaller.[84]

Under the statute, which was enacted in 1967, the Board of Water and Air Resources may delineate "capacity use areas" where uses of water (1) have developed or threatened to develop to a degree which requires coordination and regulation, or (2) exceed or threaten to exceed, or otherwise threaten to impair, the renewal or replenishment of such waters.

The law also allows the Board, without delineating an area, if it finds use or pollution will result in water depletion or pollution, to prohibit or limit withdrawals in excess of 100,000 gallons per day, and to prohibit facility construction of capacity in excess of 10,000 gallons per day or more.

In a "capacity use area", the Board must issue a permit for nonconsumptive uses, where the proposed use is consumptive, the Board must deny it if its effect would be "contrary to public interest". Uses in existence prior to delineation are to have priority, to the extent that they are reasonably necessary. The Board is also authorized to modify or revoke a permit on 60 days' notice. Permits are issued for a ten year period; renewal is the same as applying for a new permit.

In issuing permits or adopting regulations, the Board is directed by the statute to consider:

1. The number of persons using an aquifer or stream and the object, extent and necessity of their respective withdrawals or uses;
2. The nature and size of the stream or aquifer;
3. The physical and chemical nature of any impairment of the aquifer or stream, adversely affecting its availability or fitness for other water uses (including public use);
4. The probable severity and duration of such impairment under foreseeable conditions;
5. The injury to public health, safety or welfare which would result if such impairment were not prevented or abated;
6. The kinds of businesses or activities to which the various uses are related;
7. The importance and necessity of the uses claimed by permit applicants or of the water uses of the area and the extent of any injury or detriment caused or expected to be caused to other water uses (including public use);
8. Diversion from or reduction of flows in other watercourses or aquifers; and
9. Any other relevant factors.

The Board is also directed to adopt regulations for capacity use areas concerning timing of withdrawals, prevention of salt water encroachment, protection against "unreasonable adverse effects", and concerning well spacing, pumping levels, and rates. Permits must contain conditions to implement these regulations.

The Board has established one "capacity use area", including all or part of eight counties along the Atlantic Coast. Regulations adopted by the Board require that any person drilling a well in the area (whether or not they must obtain a use permit, but exempting domestic wells) must obtain a well construction permit and file a report containing specified information when completing or abandoning a well.

Where a water use permit is required, the regulation requires the Board to establish in the permit the maximum total quantity that may be withdrawn daily, allows the Board to specify the timing of withdrawals, maximum rates of withdrawal, lowest water level that may be produced in a well, and in addition allows the Board by the terms of the permit to:

a. Require that the applicant cooperate with the Department of Water and Air Resources, and with other users of water in the affected area, in determining and implementing reasonable and practical methods and processes to conserve and protect the water resources while avoiding or minimizing effects on the quantity and quality of water available to persons whose water supply has been materially reduced or impaired as a result of withdrawals made pursuant to Water Use Permits.

b. Require that any portion of the water withdrawn be returned to the source or to any other stream or aquifer as approved by the Board.

c. Require the holder of a Water Use Permit to obtain the Board's approval of the locations and distribution of individual surface water intakes and wells, and of the depths, zones, aquifers or parts of aquifers from which withdrawals may be made.

d. Require that each well or surface water intake be equipped with an approved metering device that will provide a continuous record of withdrawals within an accuracy of plus or minus five percent.

e. Require that observation stations or wells be installed and maintained for monitoring water levels and water quality.

The regulation also requires that the quantity of water be justified for each purpose for which it is requested.

The regulation requires that specific information be supplied the Board on well construction and abandonment, monthly withdrawals and use, and monthly water levels. The permit holder is also required to notify the Board of any major changes in usage, and is told that he may have to justify his continuing needs and to document water conservation measures. A permit may not be transferred without approval of the Board.

The regulations also specify that no construction or installation of works of improvement which significantly affect the quantity or quality of the water resources shall be undertaken without prior approval of the Board, including surface and subsurface drainage projects (exempting small projects), well mining projects, and excavation projects.

FLORIDA

Florida has had some water use control laws for a number of years, but in 1972 it enacted a comprehensive statute which is notable in a number of respects, one of these being its division of the state into six "water management districts" by metes and bounds description contained in the statute.[85] The water permit system may be administered by the state Department of Natural Resources; in the alternative, the statute allows the Department to delegate this authority to the board of governors of a district, which can then issue permits under regulations which it adopts to carry out a water management program for the district. (Governing boards are composed of nine residents of the district appointed by the Governor. In 1974, one district had adopted regulations,[86] and one was in the process. The other four had not initiated regulation making procedures.)

The department or the governing board:

> . . . may require such permits for consumptive use of water and may impose such reasonable conditions as are necessary to assure that such use is consistent with the overall objectives of the district or department and is not harmful to the water resources of the area.

Domestic uses and "nonconsumptive" uses are exempted from permit requirements. Permits are issued for 20 years, or 50 years if necessary to retire bonds. Considerations on renewal are the same as those for initial issuance. A permit may be revoked for non-use or for violation.

An applicant for a permit must establish that the use he proposes:

1. Is a "reasonable-beneficial use" (i.e., "the use of water in such quantity as is necessary for economic and efficient utilization, for a purpose and in a manner which is both reasonable and consistent with the public interest");
2. Will not interfere with any presently existing legal use of water; and
3. Is consistent with the public interest.

In adopting a program for an area, under which permits are to be issued, the Department or the governing board is to establish minimum flow for all surface watercourses ("the limit at which further withdrawals would be significantly harmful to the water resources or ecology of the area") and the minimum levels for both ground and surface waters. The law allows the board or Department to provide for the protection of nonconsumptive uses in the establishment of minimum flows and levels.

The Department is instructed to give careful consideration to the requirements of public recreation and the protection and procreation of fish and wildlife. It is authorized to prohibit or restrict other uses on designated bodies of water which may be inconsistent with these objectives. The governing board or the Department may by regulation:

> reserve from use by permit applicants water in such locations and quantities and for such seasons of the year as in its judgement may be required for the protection of fish and wildlife or the public health and safety. Such reservations shall be subject to periodic review and revision in the light of changed conditions; provided, however, that all presently existing legal uses of water shall be protected so long as such use is not contrary to the public interest.

The Department is also authorized to designate certain uses in connection with a particular source of supply which may constitute an undesirable use for which the governing board may deny a permit, and certain uses in connection with a particular source of supply which would result in an enhancement or improvement of the water resources of the area, which uses shall be preferred over other uses.

Where two or more applications are for a quantity of water that is inadequate for both or all, the board or Department may approve or modify the applications which best serve the public interest. If the applications are equally in the public interest, a renewal has preference over an initial application.

For purposes of water shortages, the board or Department is allowed to classify permits according to source of supply, method of extraction or diversion, or use of water, and to impose restrictions on the permits as necessary "to protect the water resources of the area from serious harm and to restore them to their previous condition". If this is not sufficient to protect "the public health, safety, or welfare, or the health of animals, fish, or aquatic life, or a public water supply, or recreational, commercial, industrial, agricultural, or other reasonable uses", the board or Department may issue orders necessary to meet the emergency, including apportioning, rotating, limiting, or prohibiting use of the water resources of the district.

The regulations adopted by the Southwest District, in addition to the constraints imposed by the statute, prohibit any withdrawal that will:

- -- Cause the flow of a stream or other watercourse to be lowered below the minimum flow established by the Board.
- -- Cause the level of the potentiometric surface to be lowered below the regulatory level established by the Board, or below sea level.
- -- Cause the level of the surface of water to be lowered below the minimum level established by the Board.
- -- Significantly induce salt water encroachment.
- -- Cause the water table to be lowered so that the lake stages or vegetation will be adversely and significantly affected on lands other than those owned, leased, or otherwise controlled by the applicant.
- -- Exceed the water crop of lands owned, leased, or otherwise controlled by the applicant. (Except where determined otherwise, the water crop (precipitation less evapotranspiration) throughout the District will be assumed to be 365,000 gallons

per year per acre.)

-- Cause the level of the potentiometric surface under lands not owned, leased, or otherwise controlled by the applicant to be lowered more than five feet.

-- Cause the level of the water table under lands not owned, leased, or otherwise controlled by the applicant to be lowered more than three feet.

-- Cause the level of the surface of water in any lake or other impoundment to be lowered more than one foot unless the lake or impoundment is wholly owned, leased, or otherwise controlled by the applicant.

Model Proposals

Some of the major features of three proposals for enactment by states are described in the following material. These are the Model Water Use Act of the National Conference of Commissioners on Uniform State Laws, after which the Iowa statute was fashioned; the recommendation of the National Water Commission; and the Model Water Code of the University of Florida, after which the Florida statute was fashioned.

Model Water Use Act. The National Conference of Commissioners on Uniform State Laws approved a Model Water Use Act in 1958. This proposal consisted of a permit system to allocate use of ground and surface water based on the standard of "beneficial use" (a use that is "reasonable and consistent with the public interest in the proper utilization of water resources, including, but not limited to, domestic, agricultural, industrial, power, municipal, navigational, fish and wildlife, and recreational uses"). Existing uses and domestic uses would be exempted. A permit could be issued if "the most beneficial use and development of the water resources of the state will not be impaired by granting the permit", and it will not substantially and materially interfere with preserved uses, domestic uses, or earlier permits. A "preserved" use is a use existing at the time of enactment, for which the user filed a declaration within three years.

Maximum duration of a permit could be 50 years, or less by regulation. Permits could be revoked for non-use, violation of law, or, if a source could not yield enough water for all, and a person applied for a more beneficial use than some existing use, the existing user could be required to relinquish his permit for reasonable compensation.

One of the features of this proposal which has not appeared in any significant way in any of the existing statutes is a mechanism which is in effect the reverse of the "delineated area" system -- the law is enacted to apply to all uses statewide, but the agency may then exempt quantities or types of use for specified areas and periods if it finds this would not be an "unreasonable impediment to the most beneficial use of the water resources of the state".

The agency would also be authorized, if it found a shortage or threatened shortage in any area of the state, to establish regulations forbidding construction of new diversion facilities or wells, initiation of new water uses, or the modification of existing uses in the area.

Unlike the existing statutes, the Model act proposed a specific provision to overcome the riparian law, as follows:

> Permits may be granted without regard to whether, under the law operative in this State prior to the effective date of this Act, the use made under the permit could have been maintained only in connection with the specific lands, a particular natural watershed, or otherwise.

National Water Commission Recommendation. In its Final Report in 1973, the National Water Commission recommended that the states consider enactment of comprehensive water allocation laws, suggesting basic features that such a statute should incorporate. The following excerpt, describing the features of this proporal, is from the Commission's Final Report, p. 281.

> The basic approach is to establish minimum flows to protect such social and ecological values as aesthetics, recreation, and the biosphere. The water remaining is subject to development for use in producing goods and services. The Commission would rely more on market forces to reallocate water to more valuable uses, and less on administrative allocation. Thus, it seeks to give permittees certainty in legal tenure and as much certainty in physical supply as the nature of the resource allows -- for the twin purposes of encouraging original investment in the quantity of water committed to development and of facilitating the transfer of water to more productive uses by means of buying and selling water rights permits.

The basic features of the Commission design are the following:

1. The permit system should apply to withdrawals existing at the time the legislation is enacted as well as to future withdrawals.
2. The permit system should apply to withdrawals of ground water

as well as surface water, whether or not the supplies are interrelated.

3. Any person or organization should be eligible to apply for and receive a permit for use of water at any location. Riparian restrictions on who may use water at what locations should be abolished.
4. The following information should be contained in each permit:
    a. the source of supply
    b. the point of diversion or well location
    c. the place of use
    d. the nature of use
    e. the volume of the withdrawal and of consumptive use, on an annual or seasonal basis, as may be appropriate
    f. the rate of withdrawal
    g. the times of use, and
    h. if practicably ascertainable, the amount of return flow and the point at which it re-enters the hydrologic system.
5. After enactment of the legislation, no new withdrawal should be allowed unless a permit has been issued; all existing withdrawals should be subject to termination unless a permit has been obtained for them within a stated period of time (e.g., 5 years).
6. Permits granted for withdrawals of water, from either surface bodies or underground aquifers, should be subject to cancellation for prolonged non-use and to modification for prolonged underuse.
7. Appropriate State administrative agencies should be delegated

authority to establish and maintain minimum flows for surface streams, and minimum water levels for lakes, to promote the public health, safety, and welfare, to safeguard private investment made in reliance on streamflow and lake levels, and to protect the public interest in fish, wildlife, recreational, aesthetic, and ecological values.

8. Water should be allocated in periods of shortage as follows:
   a. Water users who initiated their withdrawals after enactment of the permit system should be curtailed in the inverse order of the date of their permits.
   b. Water users whose withdrawals antedate enactment of the permit system should be curtailed only when supply is insufficient after all post-enactment permit holders have been curtailed; the available supply should be pro-rated among pre-enactment permittees according to volume of use.
   c. Pre-enactment permittees should be curtailed when necessary to preserve essential minimum flows.
9. Permits should be made transferable to facilitate private bargaining for the reallocation of water to more productive uses, subject to administrative restrictions to protect the interests of other permittees and the public interest in minimum streamflow.

Model Water Code, University of Florida. A Model Water Code drafted at the University of Florida was the basis for the Florida statute enacted in 1972.

The Model Water Code (and the Florida statute) allow a permit to issue only for a "reasonable-beneficial use", defined as "the use of water in such quantity as is necessary for economic and efficient utilization, for a purpose and in a manner which is both reasonable and consistent with the public interest." This incorporates the "beneficial use" of the Model Water Use Act, but adds a value judgement as to its economic and efficient utilization. The difference in operation would be as follows; under the Model Water Use Act, if there were enough water to supply the use, a permit would have to be issued unless it were shown that for some reason it would impair the "most beneficial use and development of the water resources of the state"; under the Model Water Code, and the Florida statute, even though there were enough water for all uses, the proposed use would have to be "for a purpose and in a manner which is both reasonable and consistent with the public interest," and be limited in amount to the quantity necessary for "economic and efficient utilization."

By contrast, the National Water Commission's proposal would include none of these judgements. It would allow the agency to protect certain in-stream values by regulating stream and other water levels, but would include no judgment as to the beneficial nature of the use applied for, the public interest, or proper utilization of water.

Control Point 5: CONTROL OF WELL CONSTRUCTION AND OPERATION

A. Water Wells

Most states regulate installation and abandonment of water wells, and license water well drillers. Regulations may have three functions, one a public health function to assure that wells are so constructed as to provide a safe drinking water supply, another the "consumer protection" function of ensuring an efficient well, and another being to prevent pollution of ground water through entry of surface water or polluted or mineralized ground water into aquifers containing better quality water. Older regulations tend to emphasize the public health function; a number of recent regulations are clearly directed at protection of ground water resources.

Statutes authorizing control of water well activities typically require that a permit be obtained by anyone who drills or re-opens a well, authorize an agency to adopt regulations, authorize inspection, and specify enforcement and appeal procedures. Regulations, some of which go into considerable detail, may include requirements concerning:

Information to obtain a permit
Location
Well design and construction
Well drilling equipment and materials
Pump and other equipment
Testing
Maintenance
Abandonment

Records

The following material examines water well regulations with emphasis on provisions applicable to prevention of ground water pollution.

Well Design and Construction

The Michigan regulation states that a water well shall be constructed "in such a manner as to maintain, insofar as practicable, existing natural protection against pollution of water bearing formations and to exclude pollutants from known sources".[87] The regulation then requires that a well be located (among other things) at least 150 feet from a preparation or storage area of spray materials, fertilizers, or chemicals that may result in pollution of the soil or ground water, and 50 feet from a buried sewer, septic tank, animal yard, etc. A well may not be located in an area subject to flooding unless special protections are provided. The regulation then provides that the ground surface shall be graded so that surface water is diverted away from the casing. Following these requirements, the regulation specifies the type of material, weight, and dimension of casing that may be used, and method of grouting in detail. It requires that casing shall extend at least 25 feet below the established ground surface and where possible below the pumping level in a sand or gravel well; it states that a well obtaining water from a depth of less than 25 feet shall not be used without written approval of the health officer. It requires a well casing or extension thereof to extend vertically at least 12 inches above ground surface. It specifies requirements for well casing seals and connections, pump installation, platforms, water suction and pump discharge lines, pressure tanks, and vents.

The Michigan regulation is typical in content of other state water well regulations, which vary in specifications and degree of detail. The model regulation proposed by the Ground Water Resources Institute, for example, contains more detail.[84] It first states the following objectives for determining the type of well to be constructed:

> Construction should seal off, insofar as practicable, water bearing formations that are or may be polluted.
>
> The well shall be constructed so that no unsealed opening will be left around the well.
>
> The materials that are to be a part of the permanent well shall conform to the requirements of .... these Regulations.

The model regulation contains a table of the prescribed diameter and depth of the drillhole for grouting, well and well screen diameters, minimum casing length and depth, liner diameter, and construction conditions for various combinations of water bearing formation and overburden.

(In May, 1976, the U. S. Environmental Protection Agency. published "A Manual of Recommended Water Well Construction Standards", written by the National Water Well Association, containing a substantially more detailed treatment of this subject than any state regulations or guidelines extant. Subjects included test holes, well construction procedure, casing, grouting, well screens and perforations, well filter construction, plumbness and alignment, well development, testing, disinfection, water samples and analyses, permanent well abandonment, and temporary capping.)

Regulations of a number of states contain requirements specifically directed at prevention of inter-aquifer movement of water to prevent pollution of one aquifer by another, in addition to preventing possible pollution from the surface.

The North Carolina regulation, for example, in its construction standards requires that all water bearing zones containing polluted or nonpotable mineralized water shall be adequately cased and cemented off so that pollution of underlying or overlying water bearing zones will not occur.[89] It specifically prohibits multi-screened wells that connect aquifers or zones which have differences in water quality that would result in deterioration of the water quality in any aquifer or zone, or which have differences in static water levels that would result in depletion of water from any aquifer or zone, or significant loss of head in any aquifer or zone.

The Texas regulation contains the following provisions concerning "undesirable water" overlying fresh water, and underlying fresh water:

> When undesirable water is encountered in a zone overlying fresh water, surface casing or other blank casing with a cement basket or packer shall be set at the top of the fresh water zone, or at some distance below the base of the undesirable water zone, and the annular space between the outside wall of the casing and the wall of the borehole shall be filled with cement from the base of the surface casing, or the top of the cement basket or packer to the land surface, or throughout the entire undesirable water zone.

> The necessary vertical (uphole and downhole) extent of the cementing operations in respect to an undesirable water zone will depend upon the condition of the borehole, lithology of the section penetrated or the hydrostatic pressures within the aquifers; however, all cementing programs must prohibit the contact of highly corrosive fluids with the wall of the casing.
>
> When undesirable water is encountered in a zone beneath but in hydraulic contact with the overlying fresh water zone, the part of the well opposite the undesirable water zone and lower portion of the overlying fresh water zone shall be filled with cement in order to prevent the entrance of the undesirable water into the pumping well. The lower half or the bottom 25 feet of the fresh water saturated interval, whichever is lesser, shall be sealed off.
>
> When undesirable water is encountered in a zone beneath but not in hydraulic contact with a fresh water zone, the wellbore shall be filled with cement to the base of the lowermost fresh water zone, or the wellbore below the fresh water zone may be filled with fine sand, clay or heavy mud to form a base for a cement plug to be placed between the lowermost fresh water zone and the undesirable water to form a permanent seal to prevent the upward migration of undesirable water into the fresh water zone.[90]

The Florida regulation states that in areas where, as a result of construction of a well, an interchange of water between water bearing zones may occur and may result in deterioration of the quality of water in one or more zones, or loss of artesian pressure, the interchange shall be prevented through proper design or construction of the well; and that if it cannot thus be prevented, the well shall be abandoned and plugged.[91]

Maintenance

In addition to design and construction requirements, some regulations specifically require that the well be maintained in a condition to prevent pollution of ground water. The North Carolina regulation contains several specifications for this purpose, including a requirement that "broken, punctured, or otherwise defective or unserviceable casing, screens, fixtures, seals, or any part of the well head, shall be repaired or replaced, or the well shall be properly abandoned."

Abandonment

The Oregon regulation is an example of a brief form:

> Any well that is to be permanently abandoned shall be filled in a manner so as to prevent the well from being a channel allowing the vertical movement of water and a possible source of contamination of the ground water supply.[92]

The Texas regulation specifies that the well be filled with cement to the land surface, but also specifies alternatives depending upon whether there is undesirable water above or below the fresh water zone.[93]

The North Carolina regulation contains several specific requirements, including one that in the case of gravel packed wells in which casings and screens have not been removed, the casing shall be perforated opposite the gravel pack at intervals not exceeding ten feet. It specifically allows casing and screen to be salvaged. It requires that bored wells be completely filled; for wells in unconsolidated formations, it requires that this filling be done by introducing cement grout through a pipe extending to the bottom of the well which can be raised as the well is filled.

A regulation of the San Joaquin Local Health District, California (in that state regulations are local, adopted under state recommended standards), requires "destruction" of any well that no longer serves a useful purpose, or has fallen into such a state of disuse or disrepair that it may become a source of impairment to ground water quality.[94] The regulation is thorough, requiring that the interior of the casing first be cleaned to eliminate obstructions that might interfere with sealing procedures. It specifies filling of the well, with the following additional requirement:

> If there is no annular seal or if occurrence is unknown, the casing shall be perforated upward beginning just above the filler material for a distance of approximately five (5) feet. Grout shall be applied above the filler material in such a manner that

the grout will be forced out of the holes, forming a barrier to the vertical movement of water.

The regulation also requires, for the protection of the seal and to facilitate future use of the land site, that a three foot hole be excavated around the drill casing, the casing cut off six inches above the bottom of the hole, and that during the sealing operation the grout used to fill the well be allowed to spill over into the excavation and fill it for a thickness of one foot and form a cap which has a diameter of at least one foot greater than the diameter of the originally drilled hole. The excavation is then filled with soil.

A San Joaquin County ordinance authorizes the district health officer to destroy any well that is polluted or so located as to become polluted or is a safety hazard, and to recover the cost of destruction from the owner of the property on which the well is located.[95]

B. Oil and Gas Wells

Regulation of the drilling of wells and other operations in connection with oil and gas production has been primarily motivated by a recognition by oil and gas producers of the need for orderly development of oil fields in order to prevent waste of the resource and the economic waste which results from unregulated competition for the resource. Many of the provisions directed at prevention of waste, such as well construction and abandonment requirements, also work to prevent water pollution. Each oil and gas law also contains specific provisions for the protection of water resources.

The terms of state water pollution control laws generally apply to pollution of surface and ground water from oil and gas operations. Provisions in oil and gas laws to prevent water pollution are in addition to those of the water pollution control laws, providing in effect special requirements that are inherent in other oil and gas regulatory activities.

A typical law regulating oil and gas production activities requires that an operator prior to drilling submit certain information in order to obtain a permit, post a bond to ensure compliance with the law, and that he follow the statute, regulations, and orders of the administering agency in drilling, casing, cementing, producing, waste disposal, reporting, fluid injection, and abandonment and plugging. The law will contain provisions for minimum acreage and minimum distance concerning location of wells, procedures for pooling and unitization, safety requirements, and inspection. It will contain general prohibitions against pollution of water resources, and some specific provisions affecting water pollution.

General Requirements Concerning Water Pollution

The Kansas regulation is an example of a general requirement:

> Fresh water, whether above or below the surface, shall be pro-

tected from all avoidable pollution, whether in drilling, plugging, or producing.[96]

This type of general statement or prohibition is common in the state statutes and regulations governing oil and gas well drilling. As in the Kansas regulation, it is accompanied by various specific provisions directed at prevention of water pollution.

Regulation of Specific Practices Affecting Water Pollution

The Interstate Oil Compact Commission recently made a survey of state requirements concerning prevention of water pollution resulting from oil and gas operations. The survey covered, in part:

1. Protection of fresh water aquifers penetrated by oil and gas drilling operations.
2. Salt water pollution resulting from oil and gas operations, and monitoring of salt water disposal and secondary recovery water injection wells for leakage.
3. Plugging of wells where leases have been abandoned and no responsible parties can be found or where individuals are financially unable to plug the well.

These three subject headings represent the three major potential sources of ground water pollution from oil and gas well drilling operations. The following material refers both to the results of the survey and to specific regulations.

1. Protection of fresh water aquifers penetrated by oil and gas drilling operations. The survey found that all but a few states require installation of surface pipe to protect all known fresh water aquifers penetrated by oil and gas drilling operations, and that this "string" be cemented to the surface.

"Surface pipe" is the outside casing of a well that is primarily depended upon to support and protect the well. Other casing is set inside this casing. It runs from the surface to various depths, depending upon the type of well, geological formations, presence of water, and other considerations. Cement is required to be placed in the space between the outside of the casing and the sides of the borehole to prevent fluids or gases from moving up or down outside the casing.

An example of a regulation stated in general terms is that of Kansas:

> Every person, who shall drill, or cause to be drilled a well or test hole, for any purpose, that penetrates formations containing oil, gas, fresh water, mineralized water, or valuable minerals, shall case or seal off such formations as may be necessary to effectively prevent migration of oil, gas, or water from or into strata that would be damaged by such migration. The effectiveness of such casing or sealing off shall be tested in such manner and by such methods and means as may be necessary, or as may be prescribed or approved by the commission, or its authorized representatives.[97]

An example of a relatively detailed regulation is that of Texas:

RULE 13. CASING

A. (1) The operator of any well drilled in any field or area shall be required to set and cement a sufficient amount of surface casing to properly protect fresh water sands which are now, or may be, a source of water supply for the area or field. Cementing shall be by the pump and plug method and sufficient cement shall be used to fill the calculated annular space back of the casing to the surface of the ground or to the bottom of the cellar. In areas where pressure conditions are unknown, or are known to be high, a blowout preventer, control head, and other connections to keep the well under control at all times shall be installed as soon as surface casing is set. The blowout preventer shall be of such type of construction and operation as to satisfy any test which may be required by the Commission or its duly accredited agent.

2. (a) Exception to the cementing requirements called for in this rule may be granted by the Commission on application. An operator shall, before drilling and setting casing in his first well in a field or area, obtain from the Texas Water Development Board a letter stating where the fresh water sands are found in the area or field in question. Such operator must set the surface casing to the depth recommended by the Texas Water Development Board to protect all fresh water sands. However, in lieu of setting the full amount of surface casing required to protect fresh water sands in the area or field in which there are no

> field rules in effect, and in fields wherein special rules require the setting of a specific amount of surface casing to protect all fresh water sands an operator may, upon written application to the Commission, use the multi-stage cementing process. When an operator wishes to use the multi-stage cementing process, he must outline in his application to the Commission the minimum amount of surface casing desired to be set before operations are commenced, and permission must be obtained from the Commission. After the operation is completed, he must then file with the Commission an affidavit made by the cementing company's representative showing where the stage cement tool was set and the number of sacks of cement used in the operation.[98]

The Texas regulation also contains general requirements for casing, requiring that the program include at least three strings of pipe in addition to the drive pipe. It includes test pressures which the pipe must withstand.

According to the IOCC survey, most states conduct tests to determine the adequacy of the cement job, but a minority require that the tests be witnessed by state inspectors.

Almost all states require that when the well is abandoned, a cement plug be made at the bottom of the surface pipe. Typical size of such a plug is 50 feet, but Florida requires a 200 foot plug. Almost all states also require that a cement plug be placed at the top of the surface pipe.

A typical regulation requires notification of intent to plug and abandon a well, so that the administering agency may give instructions for plugging. The Michigan regulation states that these instructions shall:

> . . . specify the type and amount of plugging material to be used, the depths at which bridges are to be set, the depths and lengths of cement plugs, and any special requirements which may be necessary for the proper plugging of the well.[99]

That regulation also states:

> All oil, gas, brine, and fresh water shall be confined to the strata in which they occur by the use of mud-laden fluid, cement, other suitable material, or combinations thereof. The amount, type and kind of material and the method of placement shall be prescribed or approved by the supervisor.

The Texas regulation is more detailed. The part of it that refers specifically to protection of water is as follows:

> (d) When insufficient surface pipe is set to protect fresh water horizons and they are exposed when production casing is removed from the well, or as a result of production casing not being run, a cement plug shall be placed from fifty (50) feet below the base of the deepest fresh water sand to fifty (50) feet above the top of the sand. This plug shall be proven by tagging with the drill string and respotting if necessary. A one hundred (100)

foot cement plug shall also be placed from fifty (50) feet below the shoe of the surface casing to fifty (50) feet above it.

(e) Additional cement plugs shall be placed to adequately cover and contain any high pressure gas or water sands OR AS MAY BE REQUIRED BY THE DISTRICT DIRECTOR. (Emphasis in the regulation.)[100]

2. Salt water pollution resulting from oil and gas operations, and monitoring of salt water disposal and secondary recovery water injection wells for leakage. The survey indicated that most states allow use of earthen pits or lagoons for storage or disposal of brine produced in connection with oil or gas; however, a number of these states severely restrict their use.

States control brine in various ways. Those that allow pits may require that they be impermeable, or that they be used in limited situations, or not be used where they might cause pollution.

Colorado has a detailed regulation on retaining pits for the storage of produced water which states general requirements and a special permit procedure. It requires:

Pits shall be kept free of surface accumulations of oil;

Each operator shall file an Affidavit of Condition of Operator's Retaining Pits on the 10th day of each month;

If the waters to be contained in any retaining pit are of such salt, brackish or other quality as to cause pollution if they

> were to reach other waters of the state the pit shall be constructed, maintained and operated so as to prevent any surface discharge that directly or indirectly may reach the waters of the state and also lined so as to prevent seepage where the underlying soil conditions are such as to permit such seepage reaching subsurface fresh waters.[101]

The regulation then states that no statewide rule governing construction and lining of pits is adopted due to the varying conditions that may be encountered, but that early planning for non-polluting disposal must be inaugurated. Following is a summary of provisions applicable to retaining pits constructed after August 1, 1971:

1. Except for temporary storage and disposal of substances produced in the initial completion and testing of wells, no retaining pit may be constructed without a permit.
2. Application shall include legal location, plan showing complete battery for storage, map of surface water resources and ditches, plan for the pit including proposed lining, a detailed log describing soil in which the pit to be constructed and strata between the bottom of the proposed pit and top of the nearest fresh water source below the pit (including percolation studies if required), statement of proposed final disposition and amount of produced water, chemical analysis of water to be stored and of the fresh water next below the bottom of the pit and all other fresh water strata that might be affected, and any other pertinent

information showing that anticipated operation of the proproposed retaining pit will not violate the intent of the Colorado Water Pollution Control Act.

3. A hearing will be held after notice to all interested parties.
4. The Commission may require lining or other water proofing of treatment and retaining pits, chemical or other water treatment, installation of monitoring systems and provisions for reporting requirements.

The regulation also states that as soon as practicable and economically feasible after production is established in any field, all produced water shall be disposed of underground.

A new Ohio regulation requires that all water produced from a well be stored in steel tanks before disposal by injection.[102] Wells completed prior to the effective date of the regulation may continue to use pits for storage.

The survey found that almost all states have a system of inspection or monitoring of injection well or other disposal systems; however, the regulations typically require only periodic reports by the operator, and that the administering agency make annual inspections. Texas requires that all wells be equipped so as to permit observation of pressure between the two strings of casing at the wellhead, so that new casing may be required if necessary.[103]

3. Plugging of wells where leases have been abandoned and no

responsible parties can be found or where individuals are financially unable to plug the well. Almost all states require that an applicant for a permit to drill an oil or gas well file a performance bond, but the survey found that most states do not provide funds for the plugging of wells where no responsible person can be located.

Most regulations require periodic reporting of all wells, including those whose production operations or use as a service well have ceased, until the wells are actually plugged. Most states also set a time limit for plugging wells after they are found to be dry or have no further utility, varying from 30 days to a year.

Control Point 6: AIR QUALITY STANDARDS

The states have enacted statutes and adopted regulations to control air pollution, primarily in response to the 1970 Amendments to the Federal Clean Air Act, which required states to meet federal standards. The statutes do not by their terms relate to pollution of ground water. Effect on ground water would result from control of pollutants which by being washed into streams or by falling on the ground could pollute ground water by infiltration or leaching, by affecting vegetation, or possibly by affecting ground water recharge by sealing stream bottoms or land areas through which recharge occurs.

A typical statute authorizes the state agency to adopt regulations for the control of air pollution, prescribing ambient air quality standards (the air outside of buildings, stacks, etc., which surrounds human plant or animal life, or property), and emission standards for the purpose of achieving ambient air-quality standards.

The statute may require that a permit be obtained for installation or operation of polluting equipment, and enable the agency to issue variances, the purpose of which is to establish conditions and deadlines for compliance with standards.

The statute enables the agency to require that monitoring devices be installed and that certain records be maintained, and reports filed, and enables the agency to make inspections and investigations, install monitoring equipment, and otherwise to enforce the law and regulations.

The Council of State Governments proposed a Model State Air Pollution Control Act in 1973.

Control Point 7: CONTROL OF LAND SPREADING OF POTENTIAL POLLUTANTS

A. Irrigation Using Waste Water

Spraying of sewage effluent on land as a disposal method is specifically regulated in only a few states. Most states treat such disposal on a case-by-case basis in light of water quality standards, the same as any other discharge. Maryland specifically requires a discharge permit for waste water effluents disposed of by means of spray or other land irrigation systems, as one of the permits used to enforce the water quality standards it has established for its three classifications of aquifers.[104]

A succinct statement of the function of ground disposal of waste water and considerations for site location and design of disposal fields appears in New York's Standards for Waste Treatment Works, Municipal Sewerage Facilities, as an introduction to presentation of detailed requirements for a design report for ground disposal of waste water:

> Ground disposal installations are normally used where the waste contains pollutants which can successfully be removed through distribution to the soil mantle. These pollutants can be removed through organic decomposition in the vegetation-soil complex and by absorptive, physical, and chemical reactions with earth materials. Preliminary considerations of a site for ground disposal should be the compatibility of the waste with the organic and earth materials and the percolation rates and exchange capacity of the soils. The ground disposal of wastewater will eventually recharge the local groundwater; therefore, the quality, direction and rate of movement and local use of the groundwater, present and potential, are prime considerations in evaluating a proposed site.
>
> It is essential to maintain an aerated zone of at least five feet and preferably more, to provide good vegetation growth conditions and removal of nutrients. It must be realized a groundwater mount will develop below after it is in use. The major factors in design of ground disposal fields are topography, soils, geology, hydrology, weather, agricultural practice,

adjacent land use and equipment selection and installation.[105]

Detailed requirements specifically directed at spray irrigation for the purpose of protecting ground water are exemplified by the Spray Irrigation Manual published by the Bureau of Water Quality Management of the Pennsylvania Department of Environmental Resources. An introduction to the manual states:

> Since roughly 50 per cent of waste waters discharged to the land surface in Pennsylvania will infiltrate and recharge ground water, all spray irrigation installations are considered discharges to the waters of the Commonwealth. As such, each installation will require a Department of Environmental Resources permit under the Clean Streams Law.[106]

The manual provides guidelines for locating and evaluating sites, and in designing spray irrigation systems. Factors include soils, geology, hydrology, weather, the agricultural practice involved, and adjacent land use. The guidelines set standards for treatment, storage, screening, controls, piping, sprinklers, distribution diameter (not in excess of 140 feet), spacing, and application rate. Following is the instruction on application rate:

> The hydraulic application rate must be selected to not exceed the infiltration capacity of the soil. The waste load applied must be adjusted to assure proper residency within the soil mantle at the hydraulic loading rate in order to achieve the desired degree of treatment. Proposed application rates will not be accepted without substantiating data. Application

> rates in excess of 1/4 inch per hour and 2 inches per week for each section of the field will be considered only under extremely extenuating circumstances supported by detailed substantiating data. Under usual conditions the ground water mound which will be built by the added infiltration should not reach within 10 feet of the ground surface. For municipal/domestic type sewage systems it will usually be advantageous to lay out the field in seven lines or sections to facilitate daily rotation of the irrigated sections. For industrial plants the number of sections is usually determined by the number of working days and/or shifts.[106]

Florida also has detailed guidelines for disposal of waste waters by irrigation. Its Department of Pollution Control specifies type of treatment for low rate (between 2 to 3 inches per week) and high rate (maximum 4 inches per week) of application for irrigation and crop harvesting, and spraying for purposes of recharge (1/40 of initial percolation rate). For each category the guidelines specify detention time for holding basin, depth to ground water (at least 5 feet for irrigation, 18 inches for recharge), and buffer zone for adjoining property. An introduction states:

> It is significant to note that provision has been made in these guidelines for use of soils as treatment media as compared to their conventional use as sinks for treated wastewaters.[107]

Idaho's regulation states that land disposal of liquid waste "shall not create a ground water mound or result in a salt build-up on another person's property". It requires that the waste water used be biologically degradable, but allows use of other waste water if it can be shown that it will have no adverse effect on underlying ground water. An applicant for a permit must "provide reasonable assurance that the earth material underlying the proposed disposal site will not allow direct rapid movement of pollutants into the underlying ground water".[108]

Guidelines and regulations typically require at least secondary treatment of wastes to be sprayed, and contain requirements for monitoring ground water. Wisconsin allows spraying of untreated dairy, canning, and meat-packing waste. It also requires monitoring of specified volumes for: municipal waste or meat-packing, if over 100,000 gallons per day; for dairy waste, if over 85,000 gallons per day; and for canning waste, if over 340,000 gallons per day.[109]

Washington requires only primary treatment, but allows land disposal only for five years in one location.[110]

The U. S. Environmental Protection Agency in its 1974 "Water Quality Strategy Paper", acknowledging the limited authority given it concerning ground water under the 1972 Federal Water Pollution Control Act Amendments, listed its incidental powers to affect ground-water quality. Among these is the following:

> Grants for the construction of publicly owned treatment works employing land disposal or aquifer recharge will be

contingent on the design of the project to meet specific groundwater quality standards in the zone of saturation for heavy metals, dissolved salts, nitrates, and organic pollutants. These criteria are contained in the definition of best practicable waste treatment technology (BPWTT).[111]

The Center for the Study of Federalism of Temple University in "The Beneficial Use of Waste Water Through Land Treatment" (1972) reported that only 14 states regulated land treatment (land disposal) of wastes. General patterns reported for a survey of all states' regulations were "a disappointing lack of information about land treatment, a great deal of misinformation, and an even greater lack of interest".[112]

California's Water Reclamation Law applies broadly to any use of treated waste water, whether for land disposal, injection for recharge, or other use. It requires each regional water quality board to prescribe water reclamation requirements for water used or proposed to be used as reclaimed water. These must be in conformance with statewide reclamation criteria established by the State Department of Health. Anyone reclaiming or proposing to reclaim water, or using or proposing to use it for any purpose for which reclamation criteria have been established, must file with the regional board a report containg such information as the board requires. Reclaimed water may not be injected directly into an aquifer that is suitable for domestic water supply until a finding by the State Department of Health, after a public hearing, that the proposed recharge will not impair the quality of water in the receiving aquifer.[113]

B. Land Disposal of Wastes

Land spreading of particular wastes is occasionally included as a subject of regulations concerning particular types of waste. For example, Maine has regulations and guidelines for septic tank sludge disposal on land (see part 3.B. above). Oregon regulates spreading of animal wastes as part of its animal feedlot regulation (see part 3.C. above). Maine has issued guidelines for manure and manure sludge disposal on land.[114]

Sewage sludge.

Regulatory provisions governing municipal sewage treatment and disposal frequently anticipate that sewage sludge will be spread on land. Oregon, for example, has a specific regulation for spreading of sewage sludge.

It requires either that sewage sludge disposal be adequately covered by specific conditions of a Waste Discharge Permit, or that a special permit be obtained based upon detailed plans and specifications. Spreading of septic-tank pumpings and raw sewage sludge is prohibited unless it is specifically determined by the Department of Environmental Quality or state or local health agency that such disposal can be conducted with assured, adequate protection of public health and safety and the environment. If non-digested sludge is spread on land within 1/4 mile of a residence, community, or public use area, it must be plowed into the ground, buried, or otherwise incorporated into the soil within five days after application. Where disposed of in a lagoon and there is a potential for ground-water contamination, monitoring wells are required.[115]

Provisions of state specifications for the operation of municipal waste treatment plants may contain specific provisions affecting land spreading of sludge. The criteria for review of waste water treatment facilities of the Colorado Department of Health, for instance, allows land spreading of stabilized sludge only. Plans must be submitted containing a detailed description of the process and design data.[116]

Illinois' Design Criteria for Waste Treatment Plants requires that ultimate disposal of sludge wastes not cause air, land, or water pollution, including ground and surface waters. A permit must be obtained from the Division of Land Pollution to dispose of non-liquid sludges, or from the Division of Water Pollution Control to dispose of liquid sludges. Basic feasibility study information is required to be submitted for review prior to submitting the detailed project design.[117] The Illinois regulation by reference incorporates requirements of the Great Lakes - Upper Mississippi River Board of State Sanitary Engineers recommended standards for feasibility studies and design proposals for ground disposal of waste waters.[118]

Industrial Sludges

In most states, the basic provision of state law applicable to land spreading of industrial sludges is the prohibition in its water pollution control law against polluting waters of the state. A state with only this provision generally has the burden of showing that pollution of surface or ground water is resulting from the sludge disposal.

Pennsylvania has changed this burden with its "potential pollution" statute, which allows the state, where storage, disposal, etc., of materials creates a danger of water pollution, or where regulation of the activity is necessary to avoid such pollution, to require by rule that the activity be conducted only pursuant to a permit issued by the Department of Environmental Resources, or it may make an order regulating the activity.[119] The Department has by rule required that a person or municipality engaged in an activity which includes the impoundment, production, processing, transporation, storage, use, application or disposal of polluting substances take all necessary measures to prevent such substances from reaching waters of the Commonwealth, directly or indirectly.[120] The Department may require a report or plan setting forth the nature of the activity and the nature of the preventative measures taken to comply with the requirement that pollution be prevented. A permit is required for land spreading of sludges. The Department is currently preparing guidelines and regulations on industrial sludges and sewage sludge.

Michigan also uses a general provision, which requires the same procedures in the case of spreading of sludge as for lagoon storage of wastes.

A person who wants to dispose of wastes on the ground must file a "new use statement", drill three initial observation wells, and file an application for a ground-water discharge permit, which is reviewed by the Water Resources Commission. The permit allows disposal of specified wastes under a specified monitoring program. The permittee must sample and report each month, and the agency also checks monthly. The Commission establishes requirements industry by industry.[121]

Various types of special laws may apply to spreading of industrial sludges, such as Massachusetts' Hazardous Waste Regulations, requiring approval of the site by the Division of Water Pollution Control;[122] New York's "Industrial Waste Scavenger" Law which requires a license for anyone engaged in the business (among other things) of scavenging or disposing of industrial process waste products including sludges, by which the Department of Environmental Conservation may control place and manner of disposal;[123] and Virginia's law regulating industrial establishments, which requires anyone constructing or operating an establishment from which there is a potential or actual discharge of wastes to state water, to provide approved facilities for treatment or control.[124]

A number of states utilize their solid-waste disposal laws. Florida's, for instance, provides that disposal of waste sludges be done with special consideration of air and water pollution, but allows them to be handled at a solid-waste site only if no alternate disposal methods are available. The general provision is a permit requirement for any activity which will "reasonably be expected to be a source of pollution".[125]

Illinois authorizes disposal of sludge in a sanitary landfill if specifically authorized by permit.[126] California's system described under Solid Waste Disposal (Control Point 3.A. above), includes sludges under its waste and site classification system that includes solid and liquid wastes.

C. Other Substances

A Massachusetts statute authorizes the Pesticide Board to adopt regulations governing pesticides, including regulations concerning application to land, as necessary to protect the public health and the public interest in soils, waters, forests, wetlands, etc. [127] The regulations require that any user obtain a permit; the Board conditions permits on an individual basis as may be required for particular applications. The regulation states:

> Pesticide applications made for agricultural purposes shall be conducted in such a manner that hazardous concentrations on adjacent lands and in adjacent waters is avoided.

The regulation prohibits pesticide application on the watershed of a public water supply unless approved by the Pesticide Board with approval of the Department of Public Health, but it does not relate specifically to ground water.

Control Point 8: CONTROL OF STORAGE AREAS

A. Storage of Waste

Various types of laws affecting waste disposal may refer to storage as distinct from disposal, such as solid waste disposal laws (part 3.A. above) and animal feedlot regulations (part 3.C. above). Deep well disposal regulations may require surface storage areas to be used in the event of malfunction of the deep well disposal system (part 3.D. above). Oil and gas drilling laws regulate surface pits used for the storage of oily wastes, water, mud, and brine from drilling and production of oil and gas (part 5.B. above). Coal strip mine reclamation laws affect storage of refuse during mining operations (part 9.A. below).

In most states, collections of industrial waste are not subject to any special regulations but are considered simply as sources of pollution which, if it can be shown that they affect or may affect surface- or ground-water quality, may be maintained only under an NPDES or a state permit. Application of these laws to industrial waste lagoons may simply be inferable from the general provisions of the statute, or specific, as in the Montana statute which specifies that the provisions of its water-pollution control law, including permit requirements, apply to:

> drainage or seepage from all sources including that from artificial, privately owned ponds or lagoons if such drainage

> or seepage may reach other state waters in a condition which may pollute the other state waters.[128]

A state with only general statutory provisions may find itself in the position of having to prove that pollution of ground water is occurring as a result of a storage activity, before it can prohibit or otherwise control the operation. It is to overcome this difficult burden that states have expanded upon their control authority in various ways.

A Pennsylvania regulation, for example, requires that impoundments for storage of industrial or other wastes be structurally sound, impermeable, protected from unauthorized acts of third parties, and that they maintain a two-foot freeboard. If a person or municipality is operating or intends to construct an impoundment to contain more than 250,000 gallons of waste, or where total capacity of several impoundments on any tract of land exceeds 500,000 gallons, or wherever the Department of Environmental Resources determines that a permit is necessary to prevent pollution, a permit must be obtained. The Department may approve the location, construction, use, operation, and maintenance of the impoundment based upon a plan that the applicant must submit.[129]

The Pennsylvania statute allows regulation by permit of impounding, handling, storage, transportation, processing or disposal activities that create a danger of water pollution, or where regulation of the activity is necessary to avoid such pollution.[130]

Michigan, without a specific regulation for lagoons, controls industrial waste collections through its water pollution control law and regulations.

The Michigan statute requires that every industrial or commercial entity which discharges liquid wastes into any surface or ground waters, underground, or on the ground, must have waste treatment or control facilities under the specific supervision and control of persons who have been certified by the Water Resources Commission as properly qualified to operate the facilities. This person must file monthly reports to the Commission showing the effectiveness of the treatment or control operation and the quantity and quality of liquid wastes discharged--subject to revocation of his certificate if he makes a false statement.[131]

In addition, the statute requires every person doing business within the state annually to report discharge of waste water (other than sanitary sewage) indicating quantities of "critical materials" used in its manufacturing processes. The Commission maintains a "Critical Materials Register" of organic and inorganic materials for this purpose.

The Michigan statute also requires a person engaged in removing liquid industrial wastes from the premises of others to be licensed and bonded, requires licensing and marking of his vehicles, and requires the licensee to keep records of materials transported and places of disposal. This law prohibits the licensee from disposing of wastes onto or into the ground except as approved by the Commission.[132] A few other states have similar laws New York's law in addition applies to septic-tank cleaners.

An approach used by some states is requirement of a permit for construction of waste-creating facilities. A rule of the Florida Department of Pollution Control requires:

> Any stationary installation which will reasonably be expected to be a source of pollution shall not be operated, maintained, constructed, expanded, or modified without an appropriate and currently valid permit issued by the Department, unless the source is exempted by Department rule. The Department may issue such permit only after it is assured that the installation will not cause pollution in violation of any of the provisions of Chapter 403, FS, or the rules and regulations promulgated thereunder.[129]

Applicable regulations are detailed, including standards for issuance or denial (the applicant must affirmatively provide the Department with reasonable assurance based on plans, test results, and other information that the activity will not cause pollution); revocation (including revocation for refusal to allow inspection); and detailed requirements for obtaining a permit, which includes:

> An engineering report covering plant description and operations, types and quantities of all waste material generated whether liquid, gaseous or solid, and proposed waste control facilities, the treatment objectives and the design criteria

> on which the control facilities are based, and other information deemed relevant. Design criteria shall be based on the results of laboratory and pilot-plant scale studies whenever such studies are warranted. The design efficiencies of the proposed waste treatment facilities and the quantities and types of pollutants in the treated effluents or emmissions shall be indicated. . . .
>
> Owners written guarantee to meet the design criteria as accepted by the Department and to abide by Chapter 403, FS, and the rules and regulations of the Department as to the quantities and types of materials to be discharged from the plant. The owner may be required to post an appropriate bond to guarantee compliance with such conditions in instances where the owner's financial resources are inadequate or proposed control facilities are experimental in nature.[133]

Delaware's regulation requiring a permit prior to construction, instead of applying only to installations which may be a source of pollution, applies to "any structure or facility the occupancy or use of which will generate liquid waste". It specifies four types of permits: (1) septic tanks (2) liquid waste treatment systems (3) bulk storage, transfer, and pipelines, and (4) sewers or pipelines carrying liquid waste. [134]

Municipal lagoons and ponds for the retention of waste water are parts of sewage treatment facilities, the construction and operation of which are supervised by state health departments or environmental protection agencies. Virtually all municipal waste treatment facilities currently are built with federal grant contributions, subjecting them to requirements established by the U. S. Environmental Protection Agency pursuant to the Federal Water Pollution Control Act Amendments of 1972. That law requires that pollutants not migrate to cause water or other environmental pollution.[135] An example of a recent state adoption of design criteria for sewage stabilization ponds is that of the Minnesota Pollution Control Agency. A number of these criteria are directed at prevention of ground-water pollution. One of these is a section on pond seal. It requires that permeability of the pond seal be as low as possible, and in no case should seepage loss through the seal exceed 500 gallons per acre per day. A testing program is required: specifications for construction and placement are to be based on test results. A minimum of four feet between the top of the pond seal and the maximum high water table is to be maintained. An approved system of ground-water monitoring wells or lysimeters is required around the perimeter of the pond site, to be determined on a case-by-case basis depending on proximity of private water supply and maximum ground-water levels. Information required to be filed prior to construction includes a log of each well within one mile of the proposed pond. The Agency also requires submission of information as required in Recommended Standards for Sewage Works, Great Lakes - Upper Mississippi River Board of State Sanitary Engineers, and Federal Guidelines, Design, Operation and Maintenance of Waste Water Treatment Facilities, U. S. EPA.[132]

B. Storage of Materials Other Than Waste

Some regulations are directed at storage of liquids, whether or not they are wastes. Delaware's regulation, for example, requires a permit for any "bulk storage", which is defined to include "any facility for the express purpose of storage of 40,000 or more gallons of any hazardous material, petroleum product or liquid waste in bulk form.[137] The permit allows control of methods so that water pollution is prevented.

Maryland has a regulation to prevent oil pollution which requires that a person obtain a permit to handle oil, including storage of any quantity of oil in excess of 10,000 gallons.[138] It requires that aboveground oil storage be surrounded with a continuous dike capable of holding the total volume of the largest container within the dike, sufficient to prevent movement of oil into the waters of the state. The regulation states that the nature of the soil and the ground water conditions at the site shall be taken into consideration in the design and location of the area. The regulation also contains requirements for equipment, and drainage of oil contaminated water.

The Maryland regulation also requires any buried tank to be protected from external corrosion by standard techniques such as coating, wrapping, cathodic protection, etc., stating that the type of protection will be determined by the nature of the soil and ground water conditions.

Minnesota has a regulation for storage of "liquid material", which prohibits storage without reasonable safeguards adequate to prevent the escape or movement of the substance whereby pollution of any waters of the state might result.[139] It requires a permit for such storage from the Water Pollution Control Commission. That regulation also requires a continuous dike to contain the liquid in case of container failure. It requires a "reasonably impervious bottom" under the entire site to prevent movement into the underlying ground in such quantity that substantial pollution of the waters of the state might reasonably be expected to result therefrom.

A 1973 Massachusetts statute prohibits storage of deicing chemicals in a manner that might affect water supply,[140] including ground water. Anyone using more than a ton in a calendar year is required to file reports. The Commissioner of Public Health is authorized to adopt regulations.

Where natural gas is stored underground, state statutes regulate the activity, largely for the purpose of protecting the gas storage operation from intrusion by other activities such as oil well drilling and other subsurface excavations. Kansas regulates "underground storage reservoirs" (natural or artificial subsurface cavities) containing petroleum products, acids, radioactive materials, or fluid or gaseous products.[141] The regulation requires submission of plans and specifications to the State Board of Health for approval, a record of products stored and injection prssures, and requires the operator to immediately report any failure or defects.[142]

Control Point 9: CONTROL OF MINING AND QUARRYING

State water pollution control law provisions typically apply to pollutant discharges from mining operations. However, states also have provisions specifically directed at mining, and water pollution from this source is controlled as an incident of mining activity.

Illinois has detailed regulations applicable to all types of mines, requiring that the operator obtain a permit from the state Environmental Protection Agency.[143] The applicant must show that the activity for which the permit is sought will not cause, threaten or allow pollution of the air or waters of the state during or after active mineral production. One of the requirements for obtaining a permit is that the applicant describe the proposed method of mining and mine refuse disposal, and the procedures which will be integrated into said methods and procedures which will be taken upon abandonment to prevent air and water pollution. An operator under such a permit is specifically required to notify the EPA of any emergency situation at the mine which causes or threatens to cause a sudden discharge of contaminants into waters, and to undertake necessary corrective measures. The regulations contain sections on mine operations, including requirements for plugging all holes; mine refuse disposal, including requirements for subsoil so that leachate will not pollute water; abandoned areas; and monitoring and reporting.

The Pennsylvania statute prohibits operation of a mine or allowing a discharge from a mine into waters of the commonwealth unless authorized or under permit.[144] It authorizes the state to require the operator to post a bond insuring compliance with the law and regulations, and conditions of the permit, including provisions insuring that there will be no polluting discharge after mining operations have ceased.

Surface mining reclamation laws commonly contain provisions directed at preventing water pollution as one of several objectives of carrying on strip mining operations with minimal damage to the environment. Provisions include the requirement that the operator obtain a license for the area to be mined, and that he first obtain approval of a plan for reclaiming the area. For the administering agency to approve the plan, it must find (among other things) that the plan does not pose a threat of water pollution. The statute will also require the operator to prevent pollution while mining and reclaiming, and condition approval of reclamation and release of his bond upon proper reclamation including prevention of water pollution.

Surface mining law and regulations also contain provisions requiring certain practices in handling of coal, soil and wastes to prevent acid production. The Wyoming statute requires to be submitted with the application for a license to mine:

> A plan for insuring that all acid forming, or toxic materials, or materials constituting a fire, health or safety hazard uncovered during or created by the mining process are promptly treated or disposed of during the mining process in a manner designed to prevent pollution of surface or subsurface water or threats to

> human or animal health and safety. Such method may include, but not be limited to covering, burying, impounding, or otherwise containing or disposing of the acid, toxic, radioactive or otherwise dangerous material.[145]

Ohio, whose coal strip mining procedure is similar to that of Wyoming, in 1974 enacted a law applicable to surface mining of other minerals such as sand and gravel, clay, and limestone.[146] That statute requires that the plan filed by the operator include a statement of the measures the operator will perform during mining and reclamation to insure that contamination of underground water supplies is prevented.

Control Point 10: CONTROL OF TRANSPORTATION AND HANDLING OF FLUIDS

A. Surface Pipelines

Interstate pipelines are under the jurisdiction of the federal Department of Transportation.

Pipelines under a state's jurisdiction may be controlled by its public utilities regulatory agency, or under a specific statute such as that of Delaware which requires a permit for construction of any pipeline facility.

B. Sewers

The possibility of ground-water pollution caused by leaky sewers has been given little attention in regulations. Where a state agency has the authority to approve sewer construction, it may as a matter of policy prohibit construction of a sewer line within a specified distance, such as 100 feet, of a well used for drinking-water purposes. The Great Lakes - Upper Mississippi River Board of State Sanitary Engineers recommended standards, followed by a number of states (see New York), requires sewer joints to be designed to minimize infiltration and to prevent entrance of roots; test requirements, however, are that leakage outward or inward not exceed 500 gallons per inch of pipe diameter per mile per day.[147]

Delaware is unusual in its requirement that one obtain a permit to construct any sewer or pipeline which conveys liquid waste.[148]

C. Spills

Various programs exist for coping with spills. These are not directed specifically at ground water protection. Ground water will not necessarily benefit from a spill response, depending upon choices made -- ground water might be better protected, for example, if a chemical were allowed to drain into a river and be diluted, rather than held behind a temporary embankment where it can infiltrate into the ground.

The National Oil and Hazardous Substances Pollution Contingency Plan provides for federal interagency response, including the Environmental Protection Agency and other federal agencies. (See Federal Register Vol. 38, No. 155, August 13, 1973.) The EPA has established ten regional Hazardous Materials Offices throughout the country to provide spill response. Spills into navigable waters are the responsibility of the U. S. Coast Guard.

The Chemical Transportation Emergency Center (CHEMTREC), a public service of the Manufacturing Chemists Association, provides 24 hour advice on chemicals that may be involved in spills. The National Agricultural Chemicals Association works through CHEMTREC in furnishing personnel, equipment, and expertise for cleanup of Class B poison pesticides.

The American Water Works Association has published an Emergency Manual on Hazardous Materials Spills to advise water utilities how to prepare for spills that may endanger water supplies.[149] The Manual contains material that would be equally useful to a state considering establishment of a state spill plan, including a "vulnerability survey" and a detailed checklist for preparation for spills.

Some states have adopted spill procedures as requirements. A Pennsylvania regulation, for instance, requires individuals responsible for a spill to immediately notify the regional office of the Department of Environmental Resources.[150] [illegible] may affect ground water, the Regional Geologist of the [illegible] Ground Water Section attempts to respond within a maximum of two hours to make a technical appraisal and enable prevention of ground water effects, if possible. Certain industries in Pennsylvania are required to develop a Pollution Incident Prevention Program which establishes a specific procedure for informing the state of spills or other major pollution problems.

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CHAPTER III

PROPOSED STATUTORY PROVISIONS TO ENABLE A STATE TO PROTECT GROUND WATER

PROPOSED STATUTORY PROVISIONS TO ENABLE A STATE TO PROTECT GROUND WATER

Preamble

The following proposal contains provisions that a state might enact if it were to be well equipped to protect ground water resources. The proposal does not require that a new agency be created, although that is one possibility. Many of the functions in the proposed statute might be assigned to the state's water pollution control agency, although they could be assigned to the state's water resources agency, its department of natural resources, department of health, or to its water use allocation agency if the state controls water use by a permit system. The "statute" could simply be used as a checklist.

This is not a proposal for a water rights law. The proposal does refer to controls on withdrawal of water, but it does not relate to allocation of water in a water rights sense.

The main thrust of the proposal is to enable state government to be sensitive to ground water quality problems, and to be sufficiently well informed that it may provide solutions to these problems. It assumes that in the case of ground water, numerous other agencies may be involved. In one alternative, it would allow a ground water agency simply to make recommendations to other agencies concerning regulations to protect ground water -- e.g., regulations controlling solid waste disposal, oil and gas well drilling, septic tank installation, and the many other activities that may affect ground water quality. The proposal's emphasis on information, the right to inspect and monitor, and assisting other agencies, stems from the nature of ground water problems -- the difficulty of finding out what is happening to ground water, and the multiplicity of controls and agencies that are needed in order to protect it.

If nothing else, the proposal suggests a means by which protection of ground water quality might be emphasized, as a cure for the present situation in which ground water protection generally is simply an incident to some other activity, and is frequently overlooked.

It would be impractical to place all functions affecting ground water quality in one agency; however, unless there is some central responsibility at least for the subject of ground water quality, it may have no competent defender.

In addition to the provisions set forth in the following material, a basic provision for state ground water programs is one that requires that a report be filed by all well drillers for each well drilled, identifying the location of the well and containing (as appropriate for the type of well drilled and the drilling method employed) information on the character and depth of formations encountered, depth at which water is encountered, static water level of the completed well, a copy of the record of pumping tests, water quality data, and construction details of the well including lengths and sizes of casing, screening, gravel packing, grouting intervals, and surface sealing.

A statute might also require that drillers of any wells, including exploratory holes, be licensed. One of the conditions of holding such a license would be compliance with requirements of the well log statute. Licensing of a commercial service is a control technique applicable to any activity where proper installation is important to protect ground water. Other activities that a state might want to consider licensing would be pump installation, septic tank installation, industrial waste disposal services, and tank inspection (for storage of liquids such as gasoline).

States that have enacted statutes to enable them to participate in the National Pollutant Discharge Elimination System would still need to enact a number of provisions in order to fully implement the following proposal because problems in ground water pollution are significantly different from those of stream pollution. Even the definition of "pollutant" used in the federal law and adopted by the states is in many ways inapplicable to ground water problems. That definition consists of a listing of types of materials that are not to be discharged into waterways without a permit. While there is some tolerance in dealing with surface water as to degree of pollution (hence, varying water quality standards), generally pollution of ground water of any sort cannot be tolerated because correction of ground water pollution, once it has occurred, is rarely feasible. Thus the ground water definition of "pollutant" (below) covers anything that could cause pollution of ground water; should exceptions need to be made, this may be controlled by conditions in a permit.

Provisions for notice and hearing, and for enforcement and penalties, can be virtually identical to those that a state may already apply to surface water pollution control, or that it may apply to administrative actions under its administrative procedure act. A state required to submit an underground injection control program under the Safe Drinking Water Act (P.L. 93-523) should consult that law and the regulations adopted under it (40 CFR Part 146) when it is examining into the adequacy of its statutes.

An aspect of ground water pollution that may not yield to treatment in a state statute such as this proposal is pollution of interstate aquifers. Pollution problems of this nature probably can be solved effectively only by adoption of an interstate compact by the states affected. The proposal does not address itself to this aspect, but it could nonetheless serve as the basis for consideration by adjoining states of provisions that would be needed in such a compact.

In examing the provisions which follow, the reader should bear in mind that one cannot draft a ground water pollution control statute as one can draft a surface water pollution control statute. Surface water pollution is a problem that can be effectively approached by creation of an agency with regulatory powers over all surface water pollution sources. Ground water pollution is too complex for such an approach. At the same time, information is a much more important ingredient for success in controlling ground water pollution. A state may very well want to keep its water data collecting program isolated from its regulatory agencies. On the other hand, if the state is to have an effective statewide program to protect the quality of ground water, an agency that is especially knowledgeable about ground water should be able to exert some influence on the many avenues of ground water pollution that exist in the state and the regulatory efforts that affect or might be made to affect them.

Thus the primary function of the following proposal is not for insertion in its entirety into a state's statutes, but rather for use by a state as an aid in analyzing or modifying its existing statutes. The provisions of the proposal are nonetheless written as statutory provisions, and can be used as such. A number owe their origin to requirements in Public Law 92-500 (the "Federal Water Pollution Control Act Amendments of 1972") and the Model Law to Enable States to Participate in the National Pollutant Discharge Elimination System suggested by the Council of State Governments to facilitate compliance with Public Law 92-500. Some provisions derive from elements of the Council of State Governments' Model State Air Pollution Control Act -- in a number of ways the problems of ground water pollution are more closely akin to those of air pollution than they are to surface water pollution. Provisions in the proposal also may resembel those of various state laws reviewed in considering this subject.

The reader who is aware of the statutory provisions in his state concerning ground water will recognize many of the following provisions and will be able to associate them with various agencies in his state. For a state that is so well equipped statutorily that the proposal appears to offer nothing new, it is hoped that the proposal might nonetheless serve as the occasion for "taking inventory" of ground water functions and appraising the effectiveness of state agencies and programs in protecting ground water.

Section 1. DECLARATION OF PUBLIC POLICY AND LEGISLATIVE INTENT

(1) It is hereby declared to be the public policy of this State and the legislative intent of this Act to protect, preserve, and enhance the quality and quantity of ground water in the State consistent with the best available technology in order to protect human health and welfare, and to promote the economic and social development of this State.

(2) To this end it is the purpose of this Act to provide for a statewide program of ground water pollution prevention, abatement, and control, and management of withdrawal and recharge of ground water, in coordination with other state, federal, and local programs for protection of human health and welfare including the State Environmental Protection Act.

This Act is in addition to Sections __________ of the statutes of this State controlling the discharge of pollutants into surface water and is supplemental to that Act as it affects the ground water of this State.

Section 2. DEFINITIONS

(1) The term "ground water" means water beneath the surface of the ground, other than soil moisture.

(2) The term "pollution" means the man-made or man-induced alteration of the chemical, physical, biological, and radiological integrity of a substance.

(3) The term "pollutant" means a substance which causes or could cause pollution of ground water.

(4) The term "source of ground water pollution" means an activity, process, or function which causes or enables a pollutant to enter the ground, or to be likely to enter the ground, in such an amount or in such a concentration as to cause pollution of ground water.

(5) The term "person" means an individual, corporation, partnership, association, the State or a political subdivision thereof, state agency, municipality, commission, or interstate body.

Section 3. POWERS AND DUTIES

The (agency) has the following powers and duties in addition to those otherwise provided in this Act:

(1) Encourage and conduct studies, surveys, research, and investigations relating to pollution of ground water and its causes, effects, prevention, abatement, and control.

(2) Collect, compile, analyze, and interpret data concerning ground water.

(3) Prepare and disseminate information concerning ground water for

use by public and private agencies and individuals.

(4) Study the hydrologic characteristics of aquifers of the State and identify those areas in which ground water is most readily polluted, and those areas that should be given special consideration because they perform a significant function in allowing recharge of aquifers; report its findings to all public agencies with jurisdiction to affect or protect ground water quality or land use in such areas, and to persons within such areas by public notice reasonably designed to inform such persons of the manner in which their interests may be affected.

(5) Prepare, develop, and maintain a plan or plans for the prevention, abatement, and control of ground water pollution in coordination with or as components of state plans concerning land use, water, and other natural resources, area-wide waste treatment management, and other planning activities by which ground water may be affected.

(6) Undertake and carry on monitoring as a continuing activity. The (agency) shall establish and maintain a statewide ground water monitoring program which shall consist of a network of ground water quality monitoring stations sampled in a systematic manner and designed to determine base-line conditions and provide early detection of pollution, and shall, to complement such network, establish and maintain a program of identification and surveillance of existing and potential sources of ground water pollution. Ground water quality monitoring shall be conducted at representative points relative to sources of ground water pollution and in areas of high utilization of ground water.

(7) Expend funds, enter into agreements, and acquire interests in real property by purchase, gift, or eminent domain, for the purpose of establishing monitoring wells and other facilities for carrying out the purposes of the Act.

(8) Hold public hearings relating to any aspect or matter in the administration of this Act, and in connection therewith, compel the attendance of witnesses and the production of evidence.

(9) Require the person owning or operating any source of ground water pollution to establish and maintain such records; make such reports; install, calibrate, use, and maintain such monitoring equipment or methods; sample such discharges (in accordance with such methods, at such locations, intervals, and procedures as reasonably may be required, including but not limited to the nature, composition, and quantities of materials produced, handled, stored, or discharged that cause or may cause ground water pollution if not properly handled, stored, or disposed of); and provide such other information relating to pollution of ground water, as the (agency) may reasonably require.

Comment: "Source of ground water pollution" is defined in Section 2, above.

(10) Require any person who causes or contributes to pollution of ground water, in any case in which correction or repair of damage to the ground water resource is feasible, to correct or repair such damage or to pay the cost or an equitable share of such cost of correction

or repair; and bring suit for the amount of such costs.

(11) Engage in action that would insure the use of the appropriate technology and effective techniques or devices for the prevention and control of ground water pollution in all areas within the State's jurisdiction.

(12) Consult with any person proposing to construct, install, or otherwise acquire a source of ground water pollution or device or system for the control thereof, concerning the efficacy of such device or system, or the ground water pollution problem which may be related to the source, device, or system.

(13) Make recommendations to state and local agencies, to the governor, and to the legislature, concerning policy, administration, and legislation affecting ground water.

(14) Establish training and educational programs to implement the declaration of public policy and legislative intent contained in Section 1 of this Act.

(15) Secure necessary scientific, technical, administrative, and operational services, including laboratory facilities, by contract or otherwise.

(16) Employ personnel and consultants as may be necessary for the administration of this Act. Subject to any applicable restrictions con-

tained in law, any department or agency of the State may from its availble resources provide the (agency) with personnel and services, with or without charge, and the (agency) may compensate other agencies for services.

(17) Provide for the establishment of advisory committees, appointment of membership, scope of investigation, and other duties, periods of duration, and terms of members.

(18) Accept, receive, and administer grants or other funds or gifts from public or private agencies, including the federal government, for the purpose of carrying out any of the functions of this Act.

(19) Institute and prosecute actions to enforce this Act.

(20) Perform other acts and duties as may be necessary to implement the declaration of public policy and legislative intent contained in Section 1 of this Act.

(21) Delegate such of its powers and duties as it may find advantageous to delegate, but it shall make public the extent of such delegation and shall retain full responsibility for the proper execution of the power or duty delegated.

Section 4. REGULATIONS

The (agency) shall adopt, amend, and repeal rules and regulations necessary to implement the provisions of this Act.

Comment: In addition to a general provision such as the above, a state will need various types of statutory authorizations to enable it to perform the complete range of activities necessary to protect ground water. Courts have frequently stricken broad delegations of regulation making authority as unconstitutional attempts to delegate legislative power -- thus if a state agency's power to adopt and enforce regulations is to be secure, the agency should be able to point to statutory standards or requirements that contain the legislative expression for which its regulations provide the detail. Statutes such as those that regulate oil and gas drilling, for example, provide numerous substantive controls and in addition authorize the administering agency to adopt and enforce regulations to implement these controls. The statute may require that a driller follow drilling procedures adequate to prevent pollution of water resources; the regulation adopted pursuant to such a statute specifies such things as casing, cementing, and well completion requirements. To be secure against constitutional attack on the ground that the statute itself attempts an improper delegation of legislative power, there should be enough language in the statute to make clear the types of controls that the legislature wants the administrative agency to effect by its rules and regulations. The degree of detail required in the statute will vary according to the practices and case law of the state concerned.

Authority to adopt regulations concerning accidental spills might read as follows:

The (agency) shall provide by rules and regulations for notification and emergency abatement procedures for accidental discharges of substances that may cause ground water pollution, and to require establishment of a system of notification and emergency abatement procedures by persons engaged in activities that are likely to result in accidental discharges.

Some powers require explicit statutory statement because of their potentially broad effect on property rights. A permit system, for instance, should be based upon a statutory prohibition against the regulated activity; the activity would be allowed only under a permit from the agency delegated to administer the law. Limitation of withdrawal of water, either to allocate use or to protect fresh water aquifers from salt water intrusion, requires clear statutory authority. Regulatory authorities affecting health have traditionally been given wide latitude by the courts, but if septic tank use is to be controlled by devices such as requiring agency approval prior to subdivision of land, such power should be contained in the statute. Similarly, regulations to control the cumulative effect of fertilizers or pesticides by limiting their use require clear statutory authority because such regulations could broadly affect farming practices that traditionally have been unregulated.

Statutes prohibiting activities without a permit should also contain authority to adopt certain administrative requirements Such as types of information to be submitted with an application for permit, authority to place conditions in a permit, etc. (See Section 8, below, on "Permit Procedure".)

Of course, a legislature may wish to give more specific instructions than are necessary to meet constitutional requirements, in order to adequately communicate its policy decisions to those who will be administering the law.

It goes without saying that a state's statutes should provide procedural safeguards affecting the process of adoption of regulations, such as requirements of notice that regulations are to be adopted, a public hearing with opportunity for those regulated to give testimony concerning desirability of the proposed regulations, and a method for those regulated to question the reasonability of the regulations in court.

Section 5. RECOMMENDATIONS AND ASSISTANCE TO OTHER AGENCIES

The (agency) shall:

(1) Prepare and recommend to the appropriate agencies the adoption of standards or regulations to protect ground water in connection with the following activities, and, upon request of another agency, perform any services on behalf of such agency in connection with the following activities, that the other agency itself has authority to perform insofar as protection of ground water is concerned:

a. Disposal of solid wastes

b. Installation, operation, and maintenance of individual sewage systems

c. Operation of animal feedlots

d. Disposal of wastes or surplus waters in wells or sumps

e. Construction and abandonment of water wells

f. Construction, operation, and abandonment of oil and gas wells and oil and gas production

g. Drilling and abandonment of exploratory holes

h. Spreading, disposal, and storage on land of substances that may cause ground water pollution, including placement in holding structures

i. Discharge of polluting substances into water and air

j. Mining, quarrying, and other excavating activities

k. Handling and storage of liquids, including installation a operation of tanks, pipelines, and sewers

l. Irrigation

m. Artificial recharge

n. Management of ground water levels and pumping rates

o. Storage of solids, liquids, and gases underground

p. Adoption of zoning and building ordinances and regulations

q. Accidental spill reporting and cleanup

Alternate addition to division (1):

If an agency to which the (agency) has recommended adoption of standards or regulations to protect ground water does not adopt standards or regulations implementing such recommendations within six months of the transmission of such recommendations, the (agency) shall request the governor to grant it authority to adopt the standards or regulations. If the governor determines that the recommended standards or regulations are authorized by law and are reasonably designed to carry out the policies declared in Section 1 of this Act, he shall by executive order authorize the (agency) to adopt the standards or regulations. Under such an order, the (agency) may adopt and enforce the standards or regulations in the same manner, with the same authority, and with the same effect as if it were the agency to which it transmitted the recommendations. Standards or regulations thus adopted may be amended or repealed only by the (agency).

Second alternate:

Same as above, except eliminate the governor, require the (agency) to adopt any standards or regulations authorized by law that are reasonably designed to carry out the policies declared in Section 1.

Comment: As a legal matter it would not be necessary to itemize the activities (a through q, above) for which the agency could recommend regulations. However, as a principle of comity, a state agency may be reluctant to inject itself into the affairs of another state agency. The purpose of the itemization is to reassure the ground water agency that it is expected by the legislature to involve itself in the regulatory activities of other agencies insofar as ground water is concerned because only in this manner can an effective program of ground water protection be implemented. The alternatives go farther -- the first requires the ground water agency to impose its ground water regulations where applicable, by intervention of the governor; the second gives the agency direct authority to adopt ground water regulations concerning any subject. The thrust of all the provisions is to communicate to the agency that the subject of ground water is its special area, in which it has primary responsibility.

(2) Review permit applications for activities that may pollute ground water, and develop and recommend provisions for permit applications to enable protection of ground water in the issuance of permits for activities and facilities that may pollute ground water.

(3) Encourage voluntary cooperation by persons and affected groups to achieve the purposes of this Act.

(4) Encourage local units of government to handle ground water pollution problems within their respective jurisdictions and on an intergovernmental cooperative basis, and provide technical and consultative assistance therefor.

(5) Advise, consult, contract, and cooperate with other agencies of the State, local governments, industries, other states, interstate or interlocal agencies, and the federal government, and with interested persons or groups.

(6) Advise and consult with the agencies of other states, and with other agencies, concerning problems in control of pollution of interstate aquifers, and prepare and encourage the adoption of interstate compacts for the protection of such aquifers.

(7) Assist public agencies, including counties, municipalities, planning commissions, and other bodies that make planning and zoning decisions, in adopting planning and zoning schemes that protect ground water quality and prevent reduction in the efficiency of ground water recharge areas.

Section 6. PERMITS

No person shall, without a valid permit from the (agency), do any of the following:

(1) Operate, maintain, or allow the operation or maintenance, of a source of ground water pollution.

Comment: This provision states a principle of broad control of activities that can pollute ground water. ("Source of ground water pollution" is defined in Section 2, above.) In a particular state, however, numerous permit systems may already exist that are directed, albeit incidentally, at prevention of ground water pollution. For instance, a state's existing permit system for prevention of pollution of streams and rivers affects ground water quality by improving the quality of streams that feed aquifers. A permit must be obtained to install a septic tank in many states; a permit must be obtained to drill an oil or gas well, and in many states to drill a water well; common also are permit requirements to dispose of solid wastes. While the provision as set forth would apply to these activities, each state would need to determine whether any new permit authority was needed to prevent ground water pollution. It would be appropriate, for example, for a ground water agency (or a ground water function within a state EPA) to administer a permit system for any lagoon disposal or storage, or land spreading of wastes. These activities, which are widely unregulated, appear to pose the major current threat to ground water quality. Because of this special threat, the ground water agency might be the state's specialist in use of lagoons and land disposal. Unlike some other activities that may be difficult to separate from other regulatory functions (e.g., well casing requirements), lagooning or land spreading could be isolated for regulation by a ground water agency. Even brine storage pits for oil and gas wells, normally regulated by the state's oil and gas agency, could be made the primary responsibility of the ground water agency on the theory that the ground water agency is the state's expert on lagoons and their potential effects. Also, the ground water agency would be an appropriate agency to administer procedures applicable to accidental spills. Generally, the agency could fill the gap in any case where a source of ground water pollution called for regulation and there was no other agency with authority to regulate the activity. Where another agency had such authority, the ground water agency's functions might be simply those of investigation, advice, and recommendation contained elsewhere in this proposal.

Comment: The Safe Drinking Water Act (P.L. 93-523) requires a state permit for underground injection, but allows a state by regulation to authorize such injection.

(2) No person shall, without a permit, withdraw ground water.

Comment: It is beyond the scope of the present report to suggest or even to discuss the enactment by a state of a law establishing a statutory system of water rights. For a description of existing water use permit systems in various states, and model proposals that have been made, the reader is referred to Control Point 4 in Chapter II.

However, a statute covering all aspects of ground water quality control would not be complete without reference to the use of permits to control withdrawal. Coastal states must control ground water withdrawal to prevent intrusion of sea water that can ruin a fresh water aquifer. Inland, prevention of migration of any type of contamination may require restrictions on pumping. Such controls require establishment of a permit system so that quantities, times, and other conditions may be specified as necessary to allow optimum use of ground water resources without causing contamination of the resource being pumped.

A permit system for ground water withdrawals may be useful in ground water management even without a control function. Periodic reporting by permit holders enables production of a body of information on water use and water quality which a state may use to observe trends in water use and quality, and thus to anticipate problems.

(3) No person shall, without a permit, significantly interfere with the natural recharge of ground water aquifers.

Comment: Preservation of recharge capability does not necessarily protect ground water quality, but it is one aspect of ground water protection since it preserves the function of a ground water aquifer as a water supply reservoir. An alternative is to provide artificial recharge to replace lost natural recharge capacity or to augment the natural capacity of an aquifer.

A permit system for protection of recharge areas is essentially a type of zoning intended for those limited areas such as flood plains above valley-fill aquifers which are critical to the continued recharge of large volume aquifers, but which under usual practices are gradually covered with buildings, parking lots, and roads without any recognition of the effect on water supply. A permit system lends itself to the imposition of conditions, such as requirements that a land use that has a covering effect be designed to prevent loss of infiltration by use of permeable materials where feasible, by a type of construction that minimizes covering, or that such uses be required to compensate for loss of infiltration by alternative recharge facilities, or by contribution to a central recharge facility. The effect of such requirements on ground water quality (whether beneficial or adverse) would be a consideration in designing permit conditions, and in considering alternatives to natural recharge.

Section 7. PROHIBITION AGAINST ISSUING PERMIT IN CERTAIN INSTANCES

No permit shall be issued authorizing any activity that is a source of ground water pollution or is a discharge of a pollutant as defined in the Federal Water Pollution Control Act, as amended, and the activity involves:

(1) The disposition of any radiological, chemical, or biological warfare agent or high-level radioactive waste;

(2) Any discharge to which the Administrator of the U.S. Environmental

Protection Agency, or his designee, has objected pursuant to any right provided to the Administrator under the Federal Water Pollution Control Act, as amended.

(3) Any discharge which is in conflict with an area-wide waste treatment management plan approved under the Federal Water Pollution Control Act, as amended.

Comment: This section reflects the specific prohibitions contained in Public Law 92-500 (The Federal Water Pollution Control Act Amendments of 1972) that restrict issuance of permits for discharges into surface water.

Section 8. PERMIT PROCEDURE

Comment: No specific provisions are suggested here because the permit procedure should be based upon other existing permit procedures in the state. Following is a list of elements to be considered for inclusion in state permit procedures, in addition to other elements the draftsman may find necessary or desirable to place in the statute:

1. Automatic initial issuance
2. Maximum duration
3. Denial, suspension, revocation
4. Appeals
5. Bond, charge against property, insurance
6. Administrative authorities

1. Automatic initial issuance. In order to allow for delays in the initial implementation of a regulatory provision, a state may

choose to grant a permit to anyone who applies, as a matter of right, during the first 180 days (for example) after enactment of the law. Such an initial permit might be valid for a maximum period of two years, during which the agency would have power to give notice of revocation if its regulations took effect within that time and the permitted activity was in violation. This would enable the agency to achieve compliance with the regulations within the two year period but at the same time not force blanket compliance without proper tailoring to avoid specific hardships. Thereafter, all renewals should be made pursuant to regulations adopted under the Act.

Such a mechanism is in a sense a two year "grandfather clause", but it should be clear that there is no suggestion here that timely compliance will not be required for all persons who pollute or may pollute. Because the effects of ground water pollution tend to be permanent, delay in requiring compliance should be kept to a minimum.

2. Maximum duration. Permits should be limited by statute to a maximum period before requiring renewal, not to exceed five years (for example) or such additional period as may be necessary to amortize the cost of improvements and to retire bonds issued to finance improvements.

3. Denial, suspension, revocation. The statute should contain authority for the agency to deny, suspend, or revoke permits. It should state grounds therefore, such as a finding that the activity is likely to cause pollution of ground water, and the standard grounds for suspension or revocation including violation of a law, regulation, or condition of the permit; obtaining a permit by misrepresentation

or failure to fully disclose relevant facts; and change in circumstances or knowledge that requires either a temporary or permanent reduction or cessation of the permitted activity. A hearing on denial, suspension, or revocation should be required; typically, this requirement will already exist in the state's administrative procedure act. If a statute forbids issuance of a permit to any person who has had a permit revoked, as for instance in the case of forfeiture of a surety bond, special language will be required to apply to corporations where a former permit holder may attempt to change identity by formation of a new corporation.

4. Appeals. The appellate procedure for denial of a permit should likewise refer to the existing state administrative procedure act for appeals, with one major exception that is suggested here. Traditional appellate statutes relating to the granting or denying of a permit provide that the only party who may appeal a permit decision is the applicant for the permit, and only if the permit is denied. It is the intent of this Act to provide for appeal by any person adversely affected by the granting of a permit to an applicant, but such an appeal must be clearly circumscribed to prevent abuse through delay. It is suggested that any person who is a resident of the state have the power to object to the granting of a permit on the basis that the granting was based upon an arbitrary or capricious ruling of the agency, or that it is contrary to law or regulations. An appeal of the granting of a permit should be taken to the appropriate judicial body according to state law within ten days of the granting of a permit. Upon the filing of a notice of appeal and a petition for affirmative relief, the effectiveness of the permit should be suspended for a per-

iod of ten days. No further suspension of a granted permit should occur without a preliminary injunction being issued by a court of competent jurisdiction. If a preliminary injunction is issued by the court, a hearing on a permanent injunction should be required to occur within 30 days, or the preliminary injunction should become vacated by operation of law.

5. Bond. Specific situations for permits may entail the collateral use of a mandatory statutory surety bond. In the permitting of a lagoon, for instance, the agency would be given authority to adopt regulations, among others, concerning construction and operation of lagoons, and their abandonment. The statute might also state the duty of the applicant to return polluted water to its original condition. As a condition of requiring the permit, a surety bond could be required in the minimum amount of $________, plus additional amounts required by the agency that would cover the cost to the state to properly abandon the pit if the applicant fails to do it, and to repair damage to the ground water system (or other types of damage one would want to specify). The amount of the bond should be high enough to cover costs that may be incurred, but not so high as to be an unreasonable burden to carrying on the activity which the lagoon is to serve. Revocation of the permit would cause forfeiture of the bond. The bond would be released upon the lagoon properly being abandoned and the abandonment being approved by the agency.

Charge against property. Another type of authority used for the same purpose is the authority for the agency to do the work of abandonment itself and charge the landowner for the cost, adding the amount to the real estate taxes to be charged against the property.

Insurance. Requirement of a liability insurance policy might also be appropriate for protection of specific or general members of the public where there is a high probability of potential violation, either intentional or inadvertent.

6. Administrative authorities. In connection with the authority to adopt substantive regulations, the statute should also provide adequate authority for the agency to adopt necessary administrative regulations to enable it to operate the permit system effectively. This would include statements that the agency may adopt regulations concerning information required for application (including reference to plan of restoration if that is to be required), conditions of the permit (including requirements for keeping records, making reports, and maintaining monitoring wells), bond, and fees. The statute might state that technical information required by the agency must be provided by professionally qualified persons.

Section 9. INSPECTION -- RIGHT OF ENTRY.

(1) Upon reasonable evidence of a violation of this Act or rules and regulations pursuant thereto, the duly authorized officer, employee, or agent of the (agency) may, at reasonable times, enter upon any private or public property, excluding any federal building, installation, or other property, for the purpose of investigating the violation alleged. No entry shall be made upon private property without consent and without a warrant unless prior issuance of a warrant is unreason-

able under the circumstances. An application for a permit is an expressed consent to an entry without a warrant for any purpose under this Act during the pendency of such application and during the period a permit is issued and in effect.

(2) Any duly authorized officer, employee, or agent of the (agency) charged pursuant to this Act with powers or duties involving inspection for purposes of ground water pollution control may present himself before the (court) to obtain an inspection warrant. Upon a showing by affidavit of the officer, employee, or agent that there is need for entry for purposes of inspection, warrants may be issued by the court authorizing entry for the purposes of this Act and for no other purpose, without notice to the owner or operator of the premises.

(3) A person entering premises under authority of this section:

a. Shall first notify the person in apparent authority on said premises of said entry, if such a person can reasonably be found. If the entrant is unable to locate anyone in authority on the premises, entry may be made without such notice.

b. Shall be given access to review and copy any records required to be maintained for the purposes of this Act or rules and regulations pursuant thereto.

c. Shall enter for the purpose of conducting investigations and inspections authorized by this Act and for no other purpose. Such person shall not relate to any person, law enforcement agency, prosecutorial authority, or court, information gained while making such investigation or inspection which is not directly related to the investigation and inspection pursuant to this Act.

d. May conduct tests, measure flow of liquids, drill holes into the ground, and install monitoring equipment as reasonably necessary to determine the nature, amount, and extent of existing and potential ground water pollution. Upon request of the (agency), the person responsible for the premises shall provide access for sampling, testing, drilling, and installation of equipment as may be necessary to enable the making of tests and measurements, and, upon good cause shown by the agency, shall drill test holes as required by the (agency) at the applicant or permit holder's expense.

Comment: Right of entry without a warrant is limited by this section to the case where the officer has reasonable evidence of a violation of the act or regulations, for the purpose of investigating the violation, and only if prior issuance of a warrant is unreasonable under the circumstances. If the premises is under a permit, however, no warrant is required because the statute allowing entry without a warrant is an implied condition of the permit, and thus the permit holder has consented to this type of entry.

The right to enter under this section does not depend upon proof that ground water pollution has occurred. A violation of the act occurs when one operates or maintains a "source of ground water pollution" without a permit (Section 6). This phrase is defined (by Section 2) to mean "an activity in which a pollutant enters the ground or is likely to enter the ground in such an amount or in such a concentration as to cause pollution of ground water." What the definition does, thus, is to make "pollution" in effect "potential pollution" and thus allow regulation to prevent ground water pollution rather than merely to stop it once it has begun.

The limits of entry and search may be broader in a state that has declared its ground water to be the property of the state, on the theory that the state should not be required to obtain a warrant in order to inspect its property. The theory is analogous to that which pertains to wildlife, where statutes authorize game protectors to go on lands for the purpose of making investigations, even where no violation of law is suspected. Such entries would still have to be reasonable under the circumstances, however, and limited to the outdoors, specifically excluding entrance into buildings without a warrant.

The exemption of federal properties is normally included in proposals for right-of-entry provisions by the states to reflect the supremacy given to the federal government by U.S. Supreme Court interpretations of the United States Constitution. There has been considerable protest from the states that federal installations are significant offenders in the case of all types of pollution, and should not be exempted from state pollution control requirements. Although the exemption in this section is not necessary to prevent entry by state officers onto federal lands, it is included here to call attention to the actual status of the law, for the application of whatever remedy a state may wish o propse.

Section 10. CONFIDENTIALITY OF RECORDS

Any record, report, or information obtained under this Act shall be available to the public, except that upon a showing satisfactory to the (agency) by a person affected that a record, report, or information, or particular part thereof, other than data concerning pollutants, to which the (agency) has access under this Act, if made public would divulge production of financial data or methods, processes, or production unique to the person, or would otherwise tend to affect adversely the competitve position of the person by revealing trade secrets. The (agency) shall consider the record, report, or information or particular portion thereof confidential in the administration of this Act. For purposes of this section, "pollutants" includes pollutants entering the ground and pollutants above the ground surface which are likely to enter the ground.

Nothing herein shall be construed to prevent disclosure of any report, record, or information to federal, state or local agencies that may be necessary for purposes of administration of any federal, state or local pollution control laws, or when relevant in any proceeding under this Act.

Section 11. COMPLIANCE ORDERS

Whenever on the basis of reasonable evidence available to it, the (agency) finds that any person has failed to comply with a provision of this Act, or rule or regulation adopted under it, or that a person by his act or omission is preventing the (agency) from performing its powers and duties under this Act, it may issue an order (1) specifying the provision of this Act, or rule or regulation, with which the person has failed to comply or which contains the power or duty which the (agency) is prevented from performing and the facts alleged to constitute such failure to comply, or act or omission, and (2) prescribing the necessary corrective action to be taken.

Section 12. INJUNCTIVE RELIEF

The (agency) may commence a civil action for appropriate relief, including a permanent or temporary injunction, for any failure to comply, or act or omission, for which the (agency) is authorized to issue a compliance order under Section 11 of this Act. Such action shall be brought in the (court) and such court shall have jurisdiction to restrain illegal actions and to require compliance.

Section 13. CIVIL PENALTIES

Any person who violates any provision of this Act, or any permit, rule, regulation, or order issued hereunder, shall be subject to a civil penalty not to exceed $10,000 per day of such violation.

Section 14. CAUSE OF ACTION

Any person who is damaged by violation of any provision of this Act, or of any permit, rule, regulation, or order issued hereunder, shall have a cause of action for damages against the person who committed such violation.

A municipality or other public agency that conducts an activity under authority of a permit issued pursuant to this Act, which activity would otherwise be prohibited, consents to suit by any person who incurs damage as a result of the permitted activity.

Section 15. CRIMINAL PENALTIES

(1) Any person who willfully or negligently violates a provision of this Act, any permit condition or limitation, or any rule or regulation adopted under this Act, shall be punished by a fine of not less than $50 nor more than $25,000 per day of violation, or by imprisonment for not more than one year, or both. If the conviction is for a violation committed after the first conviction of such person under this subsection, punishment shall be by a fine of not less than $500 nor more than $50,000 per day of violation, or by imprisonment for not more than two years, or both.

(2) Any person who knowingly makes any false statement, representation, or certification in any application record, report, plan, or other document filed or required to be maintained under this Act or

who falsifies, tampers with, or knowingly renders inaccurate any monitoring device or method required to be maintained under this Act, shall upon conviction be punished by a fine of not more than $10,000 or by imprisonment for not more than six months, or both.

(3) Any person who willfully or negligently hinders a duly authorized officer, employee, or agent of the (agency) acting under authority of this Act shall be punished by a fine of not less than $2,500 nor more than $25,000 per day of violation. If the conviction is for a violation committed after a first conviction of such person under this subsection, punishment shall be by a fine of not less than $5,000 nor more than $50,000 per day of violation.

For purposes of this section, the term "person" means, in addition to the meaning given in Section 2 of this Act, any responsible corporate officer.

Section 16. ENFORCEMENT BY CITIZEN'S SUITS

(1) Except as provided in subsection (2) of this section, any citizen may commence a civil action on his own behalf:

a. Against any person who is alleged to be in violation of a provision of this Act, a regulation adopted pursuant to this Act, or an order issued by the (agency) with respect to such provision or regulation.

b. Against the (agency) where there is alleged a failure of the (agency) to perform any act or duty under this Act which is not discretionary with the (agency).

The (court) shall have jurisdiction to enforce such a provision or regulation or to order the (agency) to perform such act or duty, as the case may be, and to apply any appropriate civil penalties under Section 13 of this Act.

(2) No action may be commenced under subsection (1)a. of this section prior to ten days after the plaintiff has given notice of the alleged violation to the (agency).

(3) The court, in issuing any final order in any action brought pursuant to this section, may award costs of litigation (including reasonable attorney and expert witness fees) to any party, whenever the court determines such award is appropriate. The court may, if a preliminary injunction is sought, require the filing of a bond or equivalent security.

(4) Nothing in this section shall restrict any right which any person (or class of persons) may have under any statute or common law to seek enforcement of any standard or limitation or to seek any other relief.

Section 17. REMEDIES CUMULATIVE

Nothing contained in this Act in any way abridges or alters rights of action or remedies existing upon the effective date of this Act or thereafter, under the common or statutory law, but remedies provided in this Act shall be deemed cumulative to such other remedies.

Section 18. SEVERABILITY

The provisions of this Act are severable. If any provision of this Act shall be held to be unconstitutional or invalid for any reason, such unconstitutionality or invalidity shall not affect the remaining provisions of this Act.

CHECKLIST OF POWERS AND DUTIES NEEDED BY STATE GROUND WATER AGENCIES

1. Conduct studies and perform research
2. Collect data
3. Disseminate information
4. Identify critical ground water areas
5. Prepare and maintain plans
6. Conduct monitoring
7. Hold hearings
8. Require reporting by persons having ground water pollution sources
9. Require persons who pollute ground water to correct or pay cost of correction
10. Encourage technology to prevent ground water pollution
11. Consult with persons concerning ground water pollution sources and prevention techniques
12. Make recommendations concerning policy and legislation
13. Establish training and educational programs
14. Provide for advisory committees
15. Adopt regulations
16. Assist other agencies; make recommendations to other agencies for adoption of regulations affecting ground water; review permit applications for activities that may pollute ground water.
17. Prepare and encourage the adoption of interstate compacts to protect ground water.
18. Grant and revoke permits for potential sources of ground water pollution, withdrawal of ground water, and interfering with recharge.
19. Enter and inspect premises where pollution may occur.
20. Enforce law and regulations through compliance orders, injunctions, penalties, actions.

21. Exercise auxiliary powers: expend funds, make agreements, acquire property interests, employ personnel, secure technical services, accept grants, sue and be sued, delegate powers, etc.

Legal and Constitutional Basis

The right of a state to enact provisions such as the foregoing is undisputed. The general duties of the state to provide for and protect the health and welfare of its citizenry has been firmly established since the founding of the Republic.

The proposed statutory provisions and the suggested regulations pursuant thereto (see following chapter) were drafted with care having been taken to meet the justifiable ends of the state while avoiding violation of any requirements of the United States Constitution. The statutory provisions also were drafted with a view to avoiding violation of limitations or standards of the constitutions of the several states.

The provisions were prepared to be in concert with the Federal Water Pollution Control Act Amendments of 1972 (Public Law 92-500), with special attention being directed to Sections 106, 202, 208, 303, 308, 402, and 405, and with the Safe Drinking Water Act (Public Law 93-523).

Because of the time which may elapse between publication of the foregoing provisions and their adoption by a state, the state should carefully examine any "right of entry" provisions with reference to the federal constitutional requirements as set forth in the then current United States Supreme Court rulings. Section 9 of the proposed statutory provisions (above) provides for a right of entry by agency enforcement personnel into private and public properties at reasonable times for the purpose of investigating violations of the Act. This section has been drafted with particular care to be in compliance with recent interpretations of the United States Supreme Court in light of the Fourth Amendment search requirements and Fourteenth Amendment due process requirements. However, at the time of adoption of this section by a state, the State Attorney General's Office should review the requirements of the Supreme Court as they exist at that time.

Two other areas will require legal review by the State Attorney General prior to adoption.

The first involves Section 4, providing for the authority of the agency to adopt, amend, and repeal rules and regulations necessary to implement the provisions of the law. In a particular state, such an enabling statute providing rule and regulation-making authority in the base form set forth may be adequate to authorize the adoption of enforceable rules and regulations. However, state courts have frequently found particular regulations to be invalid on the ground that the statutes under which they were adopted were improper delegations of legislative power because the specific authority sought to be used in the rule or regulation was not adequately spelled out in the statute. As a result, attention must be directed to the question of what specific statutory language must be used to enable the adoption of valid regulations.

The other area requiring specific consideration in each state is section 6, subsection 2, which provides for a permit system for the withdrawal of water. As the reader has been made aware, the proposal does not indicate a preference for an order of priority which should be followed if the state regulates the withdrawal of ground water. Control Point 4 in Chapter II provides an extensive discussion of the various commonlaw and statutory rules observed by various states in ground water management. Should a state enact a law regulating withdrawal, care must be taken to review state case law and constitutional requirements to be certain that the chosen method can be carried out as desired.

Case citations are not included in this chapter because the variations in state court decisions, and lapse of time, make it difficult to produce a useful statement of the law in some vital aspects. It was felt that there being no adequate substitute for individual state review of its legal and constitutional constraints at the time legislation is being considered, case citation might prove more misleading than useful.

CHAPTER IV

REGULATIONS DESIGNED TO PREVENT POLLUTION OF GROUND WATER

INTRODUCTION

The foregoing chapter contains suggested provisions that a state legislature might enact into law. With the authority thus granted, a state administrator would need to formulate regulations that transform broad expressions of legislative intent into the specific language to control pollution of ground water.

The following regulations, or guidelines, are intended to provide state agencies with a list of requirements that may be useful to them in determining whether their existing regulations contain adequate precautions against pollution of ground water, and in determining the scope and nature of regulations that they might wish to adopt concerning activities as yet unregulated in their states. They are regulations in that they are stated in terms of requirements, but they are guidelines in that for the most part, they are preformance-oriented and are not the technical regulations that an agency would also need in order to effect detailed control of potentially polluting activities. Neither is the list all-inclusive. The hydrologic situations and types of wastes and activities that can cause pollution of ground water are almost limitless; special precautions and safeguards will need to be developed for special situations.

With each set of regulations is a statement of the rationale behind it. The reason for each regulation is not described in detail, because its purpose is generally self-evident.

From one subject to another, the regulations vary substantially in degree of detail. In some cases, no regulations are provided. The editorial judgment in each case was based upon a consideration of the potential usefulness of presenting, in this report, detailed regulations affecting the subject. Highway salting, for example, is more a matter of management than application of regulations. It was felt also that within the scope of the present manual, an attempt to propose generally applicable regulations for ground water development would not be feasible because of the variety of situations and management decisions for which such regulations must be designed. For activities such as surface water pollution control, and to some extent other activities, regulations in reference to ground water are not needed since ground water will be protected if regulation of the primary activity meets its intended objectives.

in conjunction with the following regulations, the reader should examine the Proposed Statutory Provisions for a State Ground Water Agency in the preceding chapter, to gain a perspective as to what might best be enacted by statute and what is contained in implementing regulations. This decision will vary from state to state. Some of the following regulations could themselves be used as statutory provisions.

It should be borne in mind by the reader that this report does not recommend that all the following "regulations" be adopted by all states. In a number of the following sets, regulations are alternative or they may be inconsistent with one another. A few are listed in order of decreasing stringency, from complete prohibition to general guidelines. In some states, a particular regulation to general guidelines. In some states, a particular regulation may appear extreme or unreasonable (as for instance, quantities, times, or amount of information required) while another state may find it inadequate. In any state, effective prevention of pollution of ground water will depend primarily upon the knowledgeable people whose talents are brought to bear upon the problem; the regulations which follow are offered in the hope simply that they will be useful aids to these people in fashioning a program that is appropriate for their state.

Reference to "National Drinking Water Standards" in the following material is to standards to be established by the U. S. Environmental Protection Agency pursuant to P.L. 93523, the "Safe Drinking Water Act of 1974".

In any state which has been listed under that Act by the Administrator of the U. S. Environmental Protection Agency as one for which an underground injection control program is necessary to assure that underground injection will not endanger drinking water sources, the reader should consult the federal regulations on that subject (40 CFR Part 146).

"Injection" was interpreted broadly in preparation of the federal regulations to include not only conventional cased wells, but also industrial and municipal pits and ponds, septic systems serving more than one residential unit, agricultural drainage wells, and other methods of introduction of fluids into the ground.

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1. LANDFILLES, DUMPS, AND EXCAVATIONS

Regulations for Installation, Operation, and Abandonment in order to Protect Ground Water

Sanitary landfills are generally considered to be those disposal landfills, or dumps, which are covered with soil, usually simultaneously with deposition, in a manner sufficient to minimize nuisance and health problems such as umpleasant odors, blowing papers, and vermin. These landfills are located as mounds, on top of the ground; beneath the surface of the ground, but above ground water; and beneath the surface, but below the ground water level. In many instances they present a potential hazard to ground water quality.

The significance of this hazard, in specific instances, is dependent upon the physical and chemical nature of the waste material being deposited; the geologic and hydrologic conditions prevailing at the proposed site, including their relationship to the ground water; and the economics of installation and operation.

Generally it has been the practice to dispose of toxic wastes, including pesticides, industrial by-products and residues, brines, acids, and other chemical compounds; municipal garbage; and inert or nearly inert, insoluble substances, such as masonry demolition wastes, all in a common landfill. The only protection against the obvious hazard to health has been due to fortuitous dilution -- that is, the volume of toxic products has been low enough as compared to apparently non-toxic products to prevent any widespread pollution of the ground water body.

In some states (e.g., California) waste disposal sites are classified according to the materials that may be placed in them, with toxic wastes being relegated to specific disposal sites where their disposition can be more strictly regulated and monitored.

When soluble materials in a landfill come into contact with water, the resultant leachate presents a threat to ground water quality. The source of water within the landfill may be water that was buried with the material when disposed, as in the case of a mucicipal or industrial sludge, or ground water that is in contact with the buried refuse. Most commonly it is simply rainfall that enters the disposal site

These regulations are not intended to cover all aspects of the design, construction, and operation of a sanitary landfill. They are intended only to protect ground water quality sufficiently to preserve the quality to the limits prescribed by National Drinking Water Standards and to prevent further deterioration of ground water that does not meet the Standards in its natural state.

To this objective the regulations that follow require that a permit system be initiated for all landfill operations. The most important conditions imposed by the permit requirement are:

1. A commitment as to the type of material that will be accepted at the proposed site. This includes projection of the quantity and chemical quality of leachate that is expected to be produced from the fill.
2. A complete evaluation of the geologic and hydrologic conditions existing at the proposed site.
3. A monitoring program sufficient to establish that the landfill site is performing as projected.
4. A finding that the leachate generated will not cause the indigenous ground water to exceed the level of concentrations of chemicals, including pesticides, as described in the National Drinking Water Standards. Where the indigenous quality already exceeds acceptable levels of concentration, no increase in concentration will be approved.

exceeds acceptable levels of concentration, no increase in concentration will be approved.

5. A remedial action plan, prepared in advance, available in the event leachate escapes from a landfill.

Fulfillment of these conditions will contribute substantially to the safe and economical qoperation of sanitary landfills.

These regulations should be supplemented or modified as necessary to conform with current federal regulations in 40 CFR 146 adopted pursuant to the Safe Drinking Water Act (Public Law 93-523) in any state which has been listed by the Administrator of the U. S. Environmental Protection Agency as one for which an underground injection control program is necessary to assure that underground injection will not endanger drinking water sources.

REGULATIONS

1. Every public or private agency or individual owning, constructing, or operating a landfill facility shall obtain a permit from the appropriate agency.
2. The term of the permit shall be for a maximum period of three years. The permit shall be automatically renewed every three years for the full life of the proposed facility, providing that at the end of each three-year interval restoration is current; all data and records are complete and filed with the agency, as required; and the facility is performing as projected at the time originally designed, without causing adverse effect upon local ground water conditions in excess of the National Drinking Water Standards in effect at the end of the permit period.

   In all instances the best available practicable technology shall be utilized.

3. The permit application shall contain an economic and environmental analysis of the proposed system and comparative consideration of

one or more alternative solutions.

4. The permit application shall identify the location of the proposed disposal site on the latest available topographic quadrangle map or maps of the United States Geological Survey, on a scale of 1:24,000. If no such maps are available, equivalent alternatives shall be supplied with the application.

5. The permit application shall include a detailed map, on a scale of one inch equals 200 feet, or larger, showing:
   - (a) topography within the area of the disposal site, with a contour interval not exceeding two feet,
   - (b) the area at least one-half mile beyond the site limits, which shall show contours on five-foot intervals,
   - (c) detailed survey boundaries and dimensions of the proposed project,
   - (d) cultural features, streams, springs, sinkholes, swamps, mines, pits, quarries, and other natural and man-made features as may be pertinent to ground water quality,
   - (e) existing wells, test borings, excavations, percolation test sites, etc.,
   - (f) roads, pipelines, power lines,
   - (g) location of proposed monitoring wells,
   - (h) details of ground water flow,
   - (i) location and thickness of glacial, colluvial, alluvial, and lacustrine deposits,
   - (j) bedrock depth, or outcrop, and lithology; depth to highest impermeable clay.

6. The permit application shall include a description of regional and local structural geology. Regional information shall include an area of five miles by five miles centered on the proposed site.

7. The permit application shall include a complete and detailed description of the hydrology, geology, and soils at the proposed site. This shall include, but not be limited to, description of ground water conditions; rock types, structural conditions such as faulting, folding, jointing, etc.; type and thickness of materials overlying bedrock, including soil classification; permeability and percolation rates of soils; flooding frequency; soil ion exchange capacity; gradation analyses to a depth five feet below the lowest proposed fill; and other existing conditions such as may be present at the site. A cored soil sample shall be taken and permanently retained to show initial soil characteristics.

8. The permit application shall include complete data establishing the background, or indigenous, ground water quality, including analyses for at least the following constituents:
    (a) temperature, pH, specific conductance,
    (b) hardness, alkalinity,
    (c) BOD 5 day,
    (d) COD 25 w $K_2Cr_2O_7$,
    (e) dissolved solids, suspended solids,
    (f) total iron (Fe),
    (g) manganese (Mn),
    (h) sulfate (SO_4),

(i) chloride (Cl),

(j) fluoride (F),

(k) Nitrogen - Kheldahl (N),

(l) nitrogen - ammonia (NH_4),

(m) nitrogen - nitrate (NO_3),

(n) chromium (Cr),

(o) nickel (Ni),

(p) zinc (Zn),

(q) copper (Cu),

(r) mercury (Hg),

(s) phosphorus (P),

(t) aluminum (Al),

(u) lead (Pb),

(v) methylene blue active substances (MBAS),

(w) other constituents as indicated by the nature of the material being disposed.

The permitting agency may require additional samples before issuing the permit.

9. No permit shall be issued that will result in the indigenous ground water quality becoming inferior to the physical, biological, and radiological levels for raw or untreated drinking water supply sources as specified in the National Drinking Water Standards, including future additions and modifications. If the indigenous quality is inferior to the recommended level, or

levels, for drinking water, the proposed disposal shall not degrade the naturally existing quality.

If it is determined, after issuance of a permit that the permitted activity is resulting in ground water pollution, the permit may be suspended or revoked.

10. No permit shall be issued for a landfill, dump, or excavation within the area of a floodplain covered by the 100-year flood.
11. Seasonal water level fluctuations shall be determined prior to permit approval. The maximum water table elevation shall not be within five feet of the lowest elevation of the proposed landfill unless special circumstances exist that specifically demonstrate that the proposed landfill will not adversely affect ground water quality, i.e., exceed standards.

    A minimum of two monitoring wells shall be established downgradient (water table or piezometric surface) from the proposed landfill to assure compliance with the regulations and permit conditions. These wells shall be completed so as to provide samples from that portion of the aquifer most likely to receive pollutants from the sanitary landfill, usually the upper ten feet of the aquifer.

    A regular monitoring program shall be established. Samples shall be collected at least quarterly and analysed for the components indicated under preceding Regulation 8, and other critical items that might be present as a consequence of the type of materials deposited in the fill.

An additional monitoring well shall be installed and maintained in such a location as to provide comparative data on the background ground water quality. This well shall be sampled, and the sample analysed, as above, at least annually.

All monitoring wells shall be maintained and tested for the period of the active life of the landfill, plus a minimum of three years. If the design of the landfill or other factors indicates that the possibility of pollution extends beyond the prescribed three-year period, the monitoring period may be extended by the responsible agency.

12. If pollution of ground water is suspected or proven during operation, the operator may be required to install such additional monitoring wells as designated, for both design and location, by the agency.
13. The permit application shall include a complete and detailed description of the chemical and physical character of the materials that are to be spoiled in the proposed fill. A projection shall be included of the chemical character and quantity of the leachate that will be produced.
14. The type of materials to be spoiled, and the local hydrologic and geologic materials, control the requirements for leachate handling.

(a) Where the geologic and hydrologic data required in Regulation 9 indicate that the naturally occurring soils are capable of preventing the leachate from entering the local ground water, collecting the leachate for treatment is not required to protect ground water. For example, where the disposal site is located in thick glacial clays, or in an impermeable shale, above the water table, the leachate will saturate the disposal site and appear as seeps or saturated spots on the surface. This leachate must, however, be collected and treated to prevent surface water pollution.

(b) If the disposal site is located in a permeable soil, and if the quantity and quality of the leachate is such that the quality of the ground water will be affected in excess of the acceptable standard, the disposal site shall be provided with either an underdrain system or an impermeable barrier.

  (1) Underdrain systems shall provide for collection of leachate, and either treatment to prescribe standards or direct recycling of the leachate insofar as technically feasible. When leachate is to be recycled, the ultimate disposition of the leachate, at the end of the useful life of the landfill, shall be provided.

  (2) When impermeable barriers are utilized, the useful life of the barrier shall be indicated, with provision made for assuring the continued preservation of the ground water quality.

15. The permit application shall include a detailed remedial action plan which shall be utilized in the event it is determined that leachate is escaping or has escaped from the fill site.

16. The permit application shall include the final proposed restoration plan for the site. The restoration shall be such that the restored site is compatible with the surrounding area, both aesthetically and with regard to utility.

    Restoration shall be performed concurrently with landfilling. At no time shall restoration be delayed more than ninety (90) days after active filling. Cover and drainage shall be provided daily.

17. Reports shall be submitted to the responsible agency quarterly. These reports shall include all the data obtained from the monitoring program, plus a daily record of the quantities and types of materials deposited in the landfill. Where pesticides, agricultural by-products, paint sludges, biological sludges, oils, or any similar water-soluble manufactured chemical product is being dumped separately from normal municipal rubbish, the manufacturer shall provide a complete analysis of the material dumped. No permit shall be renewed unless all reporting requirements are complied with promptly and fully.

18. The landfill operator shall provide, with the permit application, a performance bond in the amount of at least $100,000.00, or such additional amount as required by the agency as a consequence of the magnitude of the project and the wastes accepted. The bond shall be forfeited for violation of a regulation or permit condition.

19. The bond, if forfeited, will be used to restore the site. In the event of forfeiture of bond, the operator shall not be eligible for future permits.
20. In the event of violation of a regulation or permit condition, the agency may issue an order to temporarily cease operations until corrective action is taken, in lieu of bond forfeiture. Corrections must be undertaken immediately and completed within six months, without additional billing, or bond will be forfeited.

2. HOLDING PONDS AND LAGOONS

Regulations, Installation, Operation, and Abandonment in Order to Protect Ground Water

The major cause of ground water pollution in the United States, other than the use of septic tanks, is leakage of wastes from holding ponds and lagoons. These holding structures range greatly in size and are used to impound a wide variety of waste substances. In nearly all cases, unlined holding ponds and lagoons leak. This does not necessarily result in significant ground water pollution, because surrounding earth materials may be of such low permeability that the pollutants migrate only short distances, the water table may lie at depths of several tens of feet and the infiltrating wastes do not reach it, or in a few cases, pits or lagoons may be constructed in brackish or salt water areas and the waste water is less mineralized than the adjacent ground water.

Ground water pollution problems that have resulted from infiltration from holding ponds and lagoons include a broad spectrum. The most serious problems occur where underground strata are highly permeable and the wastes stored contain very mobile chemicals, such as chloride. A great number of holding ponds have been excavated in permeable sand or gravel zones, which permit the waste to infiltrate at a rapid rate. In other cases, wastes have infiltrated to nearby field drainage tile through which they have moved in relatively undiluted states to points of discharge in ditches or streams. Pollution problems such as these can be alleviated if the holding structures are lined with an impermeable membrane, such as heavy gauge plastic. Throughout the country, experience has shown that clay liners are only partially effective at controlling infiltration.

Surface runoff into holding ponds and lagoons may cause them to overflow a highly mineralized fluid that spreads out over the ground and pollutes not only the ground water, but the soil as well. The potential for this problem can be reduced by building retaining walls around each structure to prevent surface water from entering. The retaining walls, however, must be protected from erosion which could lead to catastrophic dumping during a heavy rain. Moreover, the retaining walls may be sufficiently permeable to allow waste fluids to migrate through them. This can be controlled by protecting the retaining wall with an impermeable membrane.

Studies have shown that the quality of polluted ground water in the vicinity of holding ponds varies both with depth and time. Consequently, monitoring ground water quality is not always a simple matter. Monitoring wells must be constructed in such a way that they can be used to trace the movement of fluids from a holding pond if the need arises. The number of monitoring wells needed per impoundment is dictated by the area and volume of each site, as well as the local geologic conditions. In areas where the rocks are relatively permeable and the water table near land surface, at least two adjacent monitoring wells should be installed; one should be screened near the water table, the other several feet deeper. The actual arrangement must be designed on the basis of the local geohydrologic conditions, but the well screens should be placed at a depth that will intercept a potential pollution plume.

Investigations have also shown that holding ponds and lagoons may continue to pollute ground water long after their abandonment, even though the structures have been filled with earth materials. This is largely due to collection of surface water in the vicinity of the abandoned site, where it infiltrates. Infiltrating water may leach pollutants from the former impoundment or from the fill material. This source of pollution can be controlled by means of adequate abandonment procedures.

The following regulations were developed with the above thoughts in mind. It is obvious that the regulations provided cannot solve all of the problems that might arise from the use of holding ponds and lagoons. Individual parts along with various modifications can be developed, however, into realistic management tools for the protection of ground water resources in any geohydrologic situation. Holding ponds and lagoons can be either prohibited, or allowed through a permit procedure. A public policy statement should be developed that discourages their use, but if the proposed system is technically and economically feasible and other realistic methods are not, they may be advisable, at least temporarily. As an additional safeguard, the agency could require treatment prior to placement of waste in the holding structures.

These regulations should be supplemented or modified as necessary to conform with current federal regulations in 40 CFR 146 adopted pursuant to the Safe Drinking Water Act (Public Law 93-523) in any state which has been listed by the Administrator of the U. S. Environmental Protection Agency as one for which an underground injection control program is necessary to assure that underground injection will not endanger drinking water sources.

REGULATIONS

1. Every public or private agency or individual owning, constructing, or utilizing a holding pond or lagoon for the storage of waste substances that contain water soluble materials shall obtain a permit from the appropriate agency.
2. The term of the permit shall be for a maximum period of ____ year(s), subject to renewal.
3. The permit application shall contain an economic and environmental analysis of the proposed system, including the methods of construction and maintenance, type and quantity of waste (including chemical, physical, biological, and radiological properties), proposed duration of use of the site, technical justification for the use of the proposed system in contrast to other disposal or storage techniques, and a description of the entire waste handling and disposal system.
4. The permit application shall include a complete and detailed description of the hydrology, geology, and soils at the proposed site. This shall include, but not be limited to, a description

of regional and local rock types and structural conditions, such as faulting, folding, jointing, etc.; type and thickness of materials overlying bedrock, including soil description; permeability and percolation rates of soils; soil ion exchange capacity; gradation analyses to a depth of 5 feet below the lowest proposed fill; and other existing conditions such as may be present at the site. A cored soil sample shall be taken and permanently retained to show initial soil characteristics.

5. The permit application shall identify the location of the proposed holding pond or lagoon on the latest available topographic quadrangle map or maps of the United States Geological Survey covering the site, on a scale of 1:24,000. If no such maps are available, equivalent alternatives shall be supplied with the application.

6. The permit application shall include a detailed map of the site and surrounding area within one-half mile in all directions, on a scale of one inch equals 200 feet, or larger, showing:
   - (a) topography, with a contour interval not exceeding 5 feet,
   - (b) detailed survey boundaries and dimensions of the proposed project,
   - (c) cultural features, streams, springs, sinkholes, swamps, mines, quarries, pits, and other natural and man-made features as may be pertinent to ground water quality,
   - (d) roads, pipelines, power lines,
   - (e) existing wells, test borings, excavations, percolation test sites, etc.,

(f) locations of proposed monitoring wells,

(g) details of ground water flow,

(h) location and thickness of glacial, colluvial, alluvial and lacustrine deposits,

(i) depth to bedrock, or outcrops, and lithology; depth to highest impermeable clay,

(j) faults, lineaments, fracture traces, joints.

7. Samples of ground water, in a number prescribed by the permitting agency, shall be collected for background information at the proposed holding pond or lagoon site and analyzed chemically by a qualified laboratory prior to issuance of a permit. The analysis shall include, but not be limited to, identification of specific elements, chemicals, and compounds that are present or presumed to be present in the material to be stored in the structure.

8. No permit shall be issued that will result in the indigenous ground water quality exceeding the chemical levels for raw or untreated drinking water supply sources as specified in the National Drinking Water Standards, including future additions and modifications. If the indigenous quality exceeds the recommended level or levels for drinking water, the proposed methods shall not increase the naturally existing levels.

9. A permit shall not be issued if the agency determines the information supplied indicates any hazard to the public interest.

10. A holding pond or lagoon (other than a municipal sewage lagoon) may be used only for the temporary storage of liquid, semi-liquid, or water soluble solid material.

11. Holding ponds and lagoons used for the storage of waste substances that contain water soluble materials are prohibited unless they are properly lined with leak proof material. The lining material must consist of heavy gauge plastic, compacted clay, or similar impermeable material.
12. If a clay lining is used in a holding pond or lagoon, it shall be designed in accordance with the latest technology, including consideration of the thickness, permeability, ion-exchange capacity, and life of the liner, as well as the type of waste and waste loading.
13. Fluids to be discharged into a holding pond or lagoon shall be pre-treated to remove any toxic or hazardous materials.
14. In order for a permit to be issued, an embankment or barrier that will serve as a retaining wall must surround the proposed structure. The purpose of the retaining wall is to prohibit inflow or outflow of surface water to or from the site. The retaining wall shall be of sufficient height to contain the materials involved and in addition, prevent submergence during the 100-year flood. The lagoon side of the retaining wall and the upper surface shall be protected by an impermeable liner, such as heavy gauge plastic sheeting. The level of fluid in the holding pond or lagoon shall not rise above the ground surface at any time.
15. Failure to maintain the retaining wall and liner shall be ground for revocation or suspension of the permit.
16. Pipes of any kind that penetrate or partially penetrate the retaining wall, which would permit fluids to leak from the im-

poundment, are prohibited, except where the fluids would flow into an overflow pit or facilities of equal construction designed to collect the overflow.

17. The construction of a holding pond or lagoon over field drainage tile is prohibited.

18. A holding pond or lagoon shall not be installed within the area of any floodplain encompassed by a 100-year flood.

19. A monitoring well network shall be established at each holding pond or lagoon, to assure compliance with regulations and permit. conditions. The number and location of wells shall be prescribed by the agency based upon the size and volume of the holding pond or lagoon and the subsurface hydrologic characteristics. The wells shall be located strategically to provide maximum information, but in any case within ____ feet of the holding pond or lagoon in the regional down gradient direction.

20. Samples of ground water shall be collected from the monitoring wells at regular intervals, not to exceed six months. Each sample shall be chemically analyzed by a qualified laboratory. The analysis shall include, but not be limited to, identification of specific chemicals, elements, and compounds that are present in the substances stored in the adjacent holding pond or lagoon, as specified in the permit procedure.

21. If specific chemicals, elements, or compounds known to be present in the holding pond or lagoon appear in the monitoring well samples at concentrations significantly exceeding the background concentration in the adjacent ground water, the holding pond or lagoon operation shall cease or alternative containment

procedures shall be initiated. The structure shall not be used until the repairs are completed and so certified by the operator. Within thirty (30) days, the owner or operator of the structure shall be required, at his own expense, to initiate action to return the polluted ground water to its original chemical, physical, and biological condition. The renovation work shall be completed within a time deemed appropriate by the agency.

22. The permit application shall be accompanied by a proposed plan or alternative plans of action to be followed in the event the proposed facility results in ground water pollution.
23. The operator of the holding pond or lagoon shall make an annual report to the agency on the condition of the facility. The agency may require additional reporting.
24. The permit application shall be accompanied by a performance bond, the amount of which is based upon the type, concentration, toxicity, and volume of materials to be stored.
25. The bond, if forfeited, will be used to restore the site. In the event of forfeiture of bond, the operator will not be eligible for future permits.
26. When a holding pond or lagoon is abandoned, the retaining walls shall be removed and the excavation filled with compacted fill material. The compacted fill shall be mounded at least ____ feet above the adjacent land surface, and in such a manner that with future subsidence and compaction a mound will remain. The purpose of the mound is to reduce the collection of precipitation, and resultant infiltration at the site.

27. An abandoned and filled holding pond or lagoon shall be surrounded by a drainage system, such as a ditch or drainage tile, so that surface runoff will not flow through the site. The ditch shall be constructed in such a manner that surface runoff will flow to adjacent drainage systems.

28. Following abandonment of the pit of the holding pond or lagoon and its subsequent filling, compaction, and drainage, and prior to the release of the bond, the site shall be inspected and approved by the agency.

3. WATER AND WASTE WATER SLUDGES AND EFFLUENTS

Regulations for Utilization and Disposal in Order to Protect Ground Water

There are three primary sources of significant quantities of water and waste water sludges and effluents. These are sludges resulting from municipal water treatment plants; sludges from municipal sewage treatment plants and processes; and industrial sludges.

Historically water treatment plant sludges which are predominantly lime magnesium residues resulting from water softening processes, have been discharged directly to surface streams and lakes. Recent restrictions upon this discharge have resulted in broad consideration of technological and economic alternatives. Most often, at present, the lime sludges are stored in lagoons from which the liquid effluent is decanted or evaporated. When the lagoons are filled, the sludge is allowed to air dry, and is ultimately hauled to landfill sites.

Since the moisture content of this air-dried sludge generally exceeds 50 per cent, it is difficult and expensive to haul, unsuitable for spreading, and difficult to utilize as landfill. Sludges high in magnesium content create even greater problems due to their tendency to retain even more moisture.

By utilizing vacuum filtration or centrifuge techniques it is possible to reduce the water content of the sludge to 10 to 20 per cent, making the sludge more easily utilized but at substantial expense. By firing, or recalcination, of lime rich sludge the resultant product, calcium oxide or "quicklime", can be reused in the water softening process, or utilized as agricultural lime. This procedure is of marginal value both economically and environmentally for several reasons that cannot be elaborated upon at this time. In any event, recalcination is not effective where the magnesium content of the sludge is high.

Spray irrigation and spreading or overland techniques are effective means of water treatment sludge disposal and utilization. They appear to be particularly appropriate when combined with sewage sludges and utilized for soil reclamation in areas such as strip mines. The proposed regulations provide for this mode of utilization.

Sewage sludges are commonly stored by lagooning, with the effluent discharged to surface streams. When the lagoons are full the sludge is air dried, and then hauled to waste in a landfill. As with the lime sludges, the solids content of the sludge can be increased by heat drying, vacuum filtration, and similar means. These make the sludge more amenable to utilization as landfill.

Sewage sludges that are most frequently to be dealt with are the residues of secondary treatment processes. As with other residual sludges, they must be stabilized, either chemically or biologically, prior to disposal.

Alternative methods involving incineration and land spreading of various types are being utilized with increasing frequency. Incineration reduces the quantity of the sludge that must be disposed, to three to five per cent of the initial sludge volume. This, of course, reduces problems of hauling and disposal. In addition, the ash is biologically inert, which makes it a very suitable landfill material. The most serious problems associated with incineration are cost and air pollution.

Land spreading can be utilized either with or without simultaneous application of effluent. Agricultural benefits are apparently greater when both stabilized sludge and effluent are applied. Land application techniques usually involve either irrigation by spray or surface application; overland flow by spray application; or infiltration percolation by means of spreading basin application. (USEPA, March 1974, Alternative Waste Management Technique for Best Practicable Waste Treatment.)

The advantages of land application, in addition to disposal, are, under proper circumstances: effective advanced treatment, with a high level of removal of nutrients, BOD bacteria and suspended solids; crop fertilization; and raising of ground water levels. Disadvantages include: potential ground water pollution; nitrate build-up in the soils; and possible concentration of toxic elements and compounds in the crops which may be returned directly to the food chain.

Traditionally the treatment of industrial wastes has involved only lagoons, sedimentation basins, and "evaporation" ponds. The effluent from these ponds, usually of very unsatisfactory quality, have in many instances infiltrated into the local ground water, as well as discharged into local streams directly. The polluted ground water continues to discharge into the stream, but in a diffuse manner which is often very difficult to identify. Among the worst offenders in the past have been the chemical industry, paper industry, metal processing industry, and food processors.

For the most part industrial wastes are treatable by technology similar to that of the public sewage treatment plants. Often the treatment is relatively simpler, since the waste product is specific, as compared to the broad range of substances treated in a public facility.

The variables that must be evaluated in making a determination of the appropriate technology that should be applied in a particular circumstance are numerous. The factors that must be considered include: the chemical and biological nature of the water and waste water that is to be treated; climatic factors of temperature and rainfall; geologic factors of soils and types of bedrock; hydrology and topography; and demographic and sociological factors of population, economics, land availability, and cultural features. Each of these factors involves a wide range of variable conditions, all of which cannot be rigorously defined in a set of detailed and specific regulations.

As a consequence it is considered that regulations necessary to protect ground water must be directed toward procedure and performance, rather than being detailed, specific standards, with a few exceptions. This necessitates the establishment of a permit system for the disposal or utilization of all municipal and industrial sludges and related effluents.

It is recognized that there is some redundancy or overlap between these regulations and some others. This is particularly the case with the use of holding ponds and lagoons. However, the universality of problems with the storage, utilization, and disposal of sludges, and the specificity of the problems related to them is considered to be adequate justification for treating these separately herein.

These regulations should be supplemented or modified as necessary to conform with current federal regulations in 40 CFR 146 adopted pursuant to the Safe Drinking Water Act (Public Law 93-523) in any state which has been listed by the Administrator of the U. S. Environmental Protection Agency as one for which an underground injection control program is necessary to assure that underground injection will not endanger drinking water sources.

REGULATIONS

1. Every public or private agency or individual utilizing or disposing of water treatment or waste water treatment sludges shall obtain a permit from the supervising state agency.

2. The term of the permit shall extend for the effective life of the proposed facility. The permit may be revoked at any time by the issuing agency for violation of a regulation or a condition of the permit.

3. The permit application shall contain an economic and environmental analysis of the proposed system, including a description of the biological and chemical character of the sludge and effluent; proposed duration of use of the site; a description of the entire waste handling and disposal system; and comparative consideration of one or more alternative solutions.

4. The permit application shall contain a complete and detailed description of the geology, hydrology, and soils at the proposed site. This shall include, but not be limited to, a description of regional and local rock types and structural conditions, such as faulting, folding, jointing, etc.; type and thickness of materials overlying bedrock, including soil classification; permeability and percolation rates of soils; soil ion exchange capacity; gradation analyses to a depth of 5 feet below the lowest proposed fill; and other existing conditions such as may be present at the site. A cored soil sample shall be taken and permanently retained to show initial soil characteristics.

5. The permit application shall include a detailed map of the site and surrounding area within one-half mile in all directions, on a scale of one inch equals 200 feet, or larger, showing:
   (a) topography, with a contour interval not exceeding 5 feet,
   (b) detailed survey boundaries and dimensions of the proposed project,

(c) cultural features, streams, springs, sinkholes, swamps, mines, quarries, pits, and other natural and man-made features as may be pertinent to ground water quality,

(d) roads, pipelines, power lines,

(e) existing wells, test borings, excavations, percolation test sites, etc.,

(f) location of proposed monitoring wells,

(g) details of ground water flow,

(h) location and thickness of glacial, colluvial, alluvial, and lacustrine deposits,

(i) depth to bedrock, or outcrops, and lithology; depth to highest impermeable clay,

(j) faults, lineaments, fracture traces, joints.

6. Samples of ground water, in a number prescribed by the permitting agency, shall be collected for background information at the proposed site and analyzed chemically by a qualified laboratory prior to issuance of a permit. The analysis shall include, but not be limited to, identification of specific elements, chemicals, and compounds that are present or presumed to be present in the sludge and effluent.

7. No permit shall be issued that will result in the indigenous ground water quality exceeding the chemical or pesticide levels for raw or untreated drinking water supply sources as specified in the National Drinking Water Standards, including future additions and modifications. If the indigenous quality exceeds the recommended level or levels for drinking water, the proposed disposal or utilization method shall not increase the naturally existing

levels. If there is any projected deterioration of indigenous water quality the disposal proposed shall be based upon the best available technology.

8. A permit shall not be issued if the permitting agency determines the information supplied indicates any hazard to the public interest.

9. A minimum of two monitoring wells shall be established in a down gradient (water table or piezometric surface) position from the proposed disposal site. These wells shall be completed so as to provide samples from that portion of the aquifer judged most likely to receive contamination from the disposal site, usually the upper 10 feet of the aquifer.

   A regular monitoring program shall be established, with samples collected at least quarterly, and analyzed for critical components. The monitoring wells shall be maintained for the life of the lagoon or pond, plus a minimum of three years.

   An additional monitor well shall be installed and maintained in such a location as to provide continuing data on background ground water quality.

   Seasonal water table fluctuations shall be determined prior to permit approval. The maximum water table elevation shall not be within 5 feet of the lowest elevation of the proposed disposal site, unless it can be demonstrated that the operation proposed will not result in ground water of unacceptable quality, i.e., exceed standards.

10. The permit application shall be accompanied by a proposed plan or alternative plans of action to be followed in the event the proposed facility results in ground water pollution. This shall include cessation of operation until the necessary corrections are completed.

11. No disposal site for sludges and effluents shall be installed within the area of any floodplain encompassed by a 100-year flood.

    Within any watershed the proposed site for disposal shall be protected from flooding created by the record 100-year storm.

12. For the following disposal and utilization techniques the information indicated shall be included in the permit application. Where appropriate, specific procedures and regulations are included and must be observed by the permit holder. It is strongly suggested that qualified experts in civil sanitary engineering, soils engineering, geology, and ground and surface water hydrology be utilized to supply the required data, and advise regarding the regulatory procedures:

    A. Holding Ponds and Lagoons (temporary storage only)

        (1) Type of liner. If the proposed liner is of an impervious material such as PVC plastic, a complete description of the weight and thickness of the liner, the method of installation, and the projected life of the installation shall be supplied.

            If a clay liner is to be used, the effective life of the liner, and the quality and quantity of contaminants expected to penetrate the liner shall be determined. This determination shall involve the type and thickness of clay, its permeability, exchange capacity and such other factors as may be required to make this a valid determination.

With any design of lining material, the data shall clearly indicate that the effect of any leakage from the storage site shall not cause the ground water quality to exceed the previously specified water quality standards.

B. Landfill of Sludge and Ash (permanent)

(1) The design of the landfill may be based upon either a requirement for collection and treatment of leachate, as with an underdrain system or peripheral drainage system, or a detailed evaluation indicating that the leachate will have no detrimental effect upon the naturally occurring ground water, in excess of National Drinking Water Standards.

It is recognized that in some instances the effect of leachate can be beneficial rather than detrimental, not only to existing ground water but also to biotic forms. This is particularly evident in some agricultural applications and in strip mine reclamation. In all instances the permit application shall contain a detailed analysis of existing conditions and projection of the changes anticipated as a result of the proposed project. It shall also establish monitoring procedures adequate to test the accuracy of the projections after the proposed project is in construction and operation.

(2) Landfilling may be conducted by cellular containment, or by burial in layers sufficiently thin to permit continuous daily cover and compaction.

(3) Sewage sludges that are filled in thin layers shall be covered and compacted daily. If filling is by the cellular method the cell shall be sized such that all sludge within each cell can be covered weekly. If odors from the site become objectionable beyond the boundaries of the disposal site, covering shall be conducted continuously, and daily cover shall be required.

(4) Water treatment sludges need not be covered until filling of the site is complete, unless odors develop from the site that are objectionable beyond the boundaries of the disposal site. In this event the water treatment sludge shall be covered as with sewage sludge.

(5) Industrial sludges shall be evaluated individually on the basis of their specific objectionable characteristics. Any time they become offensive by odor to surrounding properties the material being disposed shall be treated as sewage sludge.

(6) The permit application shall provide for the restoration of the site upon completion of the landfill project. This restoration plan shall include: final grading of the site on two-foot contour interval; vegetative cover,

type and location; quantity, quality, and location of leachate that will continue to discharge from site; provision for continued monitoring, and treatment of leachate, if required.

C. Land Application Techniques - Irrigation, Overland Flow, Infiltration/Percolation and Sludge Spreading

(1) In designing land application techniques the following (adopted from the Pennsylvania Department of Environmental Resources, Bureau of Water Quality Management, Publication No. 31) shall govern design criteria:

(a) TREATMENT:

All wastes must be made amenable to treatment by the earth material prior to application. In general, the equivalent of secondary treatment will be required for all organic waste prior to spraying. Higher degrees of treatment or lower hydraulic loading may be required of wastes having high BOD or COD concentrations. Care should be taken to insure that wastes containing greases and emulsions which can clog the soils and coat vegetation, preventing adequate evapotranspiration, are not discharged to the spray irrigation field. Wastes which are toxic to vegetative cover or remain toxic in the environment or are non-biodegradable or non-exchangeable with the soil materials will not be acceptable for spray irrigation. All wastes containing sewage or pathogenic organisms must be disinfected prior to spraying.

(b) STORAGE:

Storage will have to be provided where the irrigation facilities are not designed to handle surge flows or to operate in winter conditions. The size of the storage facility will depend on the volume of flow, temperature of the effluent, design of the disposal field and expected low temperature in the area. Storage facilities must be designed to handle the maximum reasonable variation in flow. These facilities are considered part of the waste treatment system and must be included in the permit application and, where applicable, must meet all department regulations with respect to impoundments (lagoons).

(c) SCREENING:

Screening should be provided in all cases where solids are expected. The screen should be designed to prevent clogging of the nozzles. The applicant must agree to establish a procedure of inspecting and cleaning the sprinklers on a routine basis. Where a solid build-up on the field may become a problem, other solid removal devices should be considered or a plan presented for incorporating the solids into the soils. Special care must be taken with greases and other liquids which can pass through the system and coagulate on the soils. The disposal of these substances through spray irrigation is very severely limited by the soil's ability to renovate the pollutants.

(d) CONTROLS:

Sufficient controls should be provided to indicate any malfunction of the disposal system, and to allow the field operation to be varied with ease. The minimum control system which will be allowed is a pressure gauge. An allowable variance of head will have to be established around the normal operating head.

(e) PIPING:

The piping should be so arranged as to allow the irrigated sections to be varied easily. Stationary (solid-set) systems are much preferred, but if a movable system is proposed, one main header must be provided with individual connections for each field section and sufficient numbers of spare equipment must be available to insure non-interrupted irrigation. Where pipe drains are necessary (particularly where winter operation is anticipated), the drains must be so arranged as to discharge only within the spray field or to return the effluent to a storage facility.

(f) SPRINKLERS:

Sprinklers should be elevated on risers high enough to insure uniform distribution with the lowest possible trajectory. They must be clear of vegetation and snow. Experience has shown that high, easily visible sprinklers are also less susceptible to destruction by farm machinery. The selection of sprinkler heads depends on the application rate, the design and distribution diameter, and the spacing of the sprinkler heads. They must be so located as to give a non-irrigated buffer zone around the irrigated area to protect against runoff. Design of the buffer zone should also consider wind transport of the waste water and odors. The revolving kicker-type sprinkler is recommended. Others will be accepted only upon submission of information showing satisfactory distribution patterns and operational ability during freezing temperatures for winter systems.

(g) DISTRIBUTION DIAMETER:

This must be selected to allow even distribution. It is dependent on the type of vegetation sprayed and is severely affected by winds and topography. The diameter should not exceed 140 feet on any type application. Generally smaller diameters are desirable in wooded areas and steeper slopes. Large distribution diameters usually involve higher trajectories and greater distortion of the distribution pattern by winds.

(h) TYPE SPACING:

The spacing must be selected to prevent overloading any part of the field. A uniform distribution of the effluent is usually most satisfactory, and will require overlapping of the spray stream in most areas. Spacings used depend on the distribution pattern of the individual sprinklers, slope, wind, and type of vegetative cover.

(i) APPLICATION RATE:

The hydraulic application rate must be selected to not exceed the infiltration capacity of the soil. The waste load applied must be adjusted to assure proper residency within the soil mantle at the hydraulic loading rate in order to achieve the desired degree of treatment. Proposed application rates will not be accepted without substantiating data. Application rates in excess of 1/4 inch per hour and 2 inches per week for each section of the field will be considered only under extremely extenuating circumstances supported by detailed substantiating data. Under usual conditions the ground water mound which will be built by the added infiltration should not reach within 10 feet of the ground surface. For municipal/domestic type sewage systems it will usually be advantageous to lay out the field in seven lines or sections to facilitate daily rotation of the irrigated sections. For industrial plants the number of sections is usually determined by the number of working days or shifts.

(j) Spray irrigation may be considered an all-season operation only in areas kept in permanent vegetation, preferably in established forest cover. Where sub-freezing operation is anticipated, drains to prevent pipe freezing should be installed and adequate temporary storage should be provided for flows that cannot be irrigated during severe weather conditions. Pipe drains must discharge only to the permitted spray field or to storage facilities. Dikes or other controls for runoff from ice build-ups must be included in the plans. Wind is also a consideration in some sections. Where strong prevailing winds are experienced a provision should be made for a windbreak or adequate buffer zone to protect downwind adjacent land usage. The trajectory of the spray should be kept as low as possible since wind velocity increases rapidly with height. Wind is also a serious consideration in distribution system design and location for uniform application of waste water.

(k) AGRICULTURAL PRACTICE:

Idle fields, forested areas, grasslands, and cultivated crop areas are acceptable for spray irrigation. The choice of vegetative cover is important both to waste renovation and water utilization through evapotranspiration. Reed canary grass has been particularly good for many sites because of its high tolerance for wet conditions and low maintenance, needing only occasional mowing. There are no restraints on the choice of vegetation, except that the vegetative cover should provide high evapotranspiration and prevent erosion from runoff. When agricultural use of the crop is anticipated, the species to be used and the harvesting frequency must be indicated. Certain crops are tolerable of wet conditions only during portions of their life span and irrigation on the barren field is unacceptable.

Acceptable slopes for the field are closely related to the agricultural practices intended. Most standard agricultural practices are acceptable for spray irrigation fields with slopes up to a maximum inclination of 4 per cent. Slopes on sodded fields are limited to 8 per cent. Forested slopes are limited to 8 per cent for year-round operation, but in some seasonal operations slopes up to 14 per cent may be acceptable.

Wastes high in nitrogen will require special care of the spray field. Nitrogen is concentrated in the growing vegetation and may build up to toxic levels in the field if the vegetation is not cut and physically removed. All fields should be mowed and the crop residue removed at least once a year. Those receiving high nitrogen loading will require more frequent cropping and removal. Mowing and removal of the crop on grassland areas will maintain better vegetative cover and improve the renovation capacity of the site for nitrogen and phosphorus.

If the spray field will be routinely disrupted for any reason (such as establishing or reestablishing a crop or cover, harvesting, field maintenance, or interment of solids) the operator must provide additional land, storage, or otherwise show in the design report that the remaining field has adequate capacity for the increased loading during the interim period. This is especially important where agricultural crops are to be grown on the spray field.

(1) ADJACENT LAND USE:

Adjacent land must be considered as it may be affected by blowing spray, odor, or other aspects of spraying. Where domestic housing is one of the neighboring land uses, the plans should include screen barriers or buffer zones to prevent blowing spray from entering residential land. Particular attention should be paid to adjacent ground water users, assuring that downgradient users of ground water have adequate protection or monitoring to prevent the use of any ground water which may become polluted. The present and anticipated use (including expansion of the spray fields) of adjoining land within 200 feet of the spray field should be considered and entered in the design report.

(2) Stabilized sludge and associated effluents may be applied by spray, ridge and furrow or other procedures, following the same general design requirements as spray irrigation, as defined under the preceding section.

(3) Where the site is to be utilized for agricultural crops the permit application shall also include the following information:

    (a) type of crops to be utilized,
    (b) estimation of concentration of heavy minerals, nitrates, or other potentially harmful constituents anticipated in the planned crops,
    (c) method of utilizing or disposing of crops.

(4) The permit application shall include the proposed loading rates of organic pollutants, including pesticides and pathogenic materials, heavy metals, dissolved salts, nitrates, and any other polluting materials that may have an adverse effect on the soils, crops, or ground water quality.

The permit application shall also project the effect, or build-up, that will result in the soils, crops, or ground water quality.

The monitoring program that is submitted with the permit application shall be adequate to test the accuracy of the projection of these changes. In the event monitoring indicates the projections were not reasonably accurate, the permit shall be reviewed, and revoked, unless it can be established that the continued operation of the system will not result in deterioration of the ground water quality in excess of National Drinking Water Standards.

13. No new permit shall be issued to any operator who is in current violation of any permit condition or regulation.

4. WASTEPILES AND STOCKPILES

Regulations for the Protection of Ground Water

Many waste materials are piled on the ground and abandoned, or stored to await final disposal. Nearly all wastepiles are uncovered and exposed to the atmosphere and precipitation, thus allowing production of leachate that may flow over the land or infiltrate. Unregulated wastepiles that contain pollutants can not only cause ground water pollution, but produce offensive odors and breed insects and other disease-carrying or disease-producing organisms.

The infiltration of water soluble substances in milling or refining wastes has caused ground water pollution. Likewise, a severe ground water quality problem arose after a soil saturated with chemical wastes was used for road grade material. The highly soluble organic wastes in the soil infiltrated, grossly polluting a nearby well.

Stockpiling of raw materials or products may inadvertently lead to ground water pollution. Many of these valuable resources may contain materials that to varying degrees are water soluble. Prime examples of stockpiles that have caused ground water pollution include salt for winter road spreading, manure for fertilizer, and certain ores.

In many instances, it is possible to control or reduce ground water pollution from wastepiles and stockpiles by providing facilities to alleviate or reduce infiltration and control surface runoff. There is such a wide variety of materials and methods used for outside stockpiling, and to a lesser extent waste disposal, that a great number of regulations will need to be developed for specific situations. All encompassing regulations are beyond the scope of this document and are left to the discretion of the agency for development.

REGULATIONS

1. Every public or private agency or individual that has or intends to have a wastepile (stockpile) of any material containing water soluble or other substances that are likely to be a source of ground water pollution shall obtain a permit from the agency. The term of the permit shall be three (3) years subject to renewal.
2. The application for a permit shall include a map or aerial photograph of the site at an appropriate scale, and describe the purpose and location of the wastepile (stockpile) site, geologic and hydrologic description of the proposed site (including rock types,

permeability, infiltration rates, description of bore hole used for examination, depth to water table, and quality of the underlying ground water), type and quantity of waste (including chemical analysis, and physical and biologic properties), proposed duration of use of the site, technical justification for the use of the proposed system in contrast to other disposal and storage techniques, and abandonment procedures.

3. Samples of ground water, the number of which shall be prescribed by the permitting agency, shall be collected for background information at the proposed wastepile (stockpile) site and analyzed chemically by a qualified laboratory prior to the issuance of a permit. The analysis shall include, but not be limited to, identification of specific elements, chemicals, and compounds that are present, or may reasonably be presumed to be present in the material to be stored in the wastepile (stockpile).
4. No permit shall be issued that will result in the indigenous ground water quality exceeding the chemical or pesticide levels for raw or untreated drinking water supply sources as specified in the National Drinking Water Standards, including future additions and modifications.
5. Disposal of waste materials on the land surface is prohibited, unless exempted. Exemptions will be automatically granted for relatively inert substances as follows: sand and gravel, quarried stone (others as appropriate).
6. Wastepiles that contain water soluble materials are prohibited unless the leachate is collected and treated in a manner to meet the conditions of the permit.

7. Stockpiled material containing substances that are likely to be a source of ground water pollution shall be placed on a surface that prohibits or significantly retards infiltration.

8. Stockpiles of materials containing substances that are likely to be a source of ground water pollution may not be stored in an unprotected condition. The stockpile must be covered by an impermeable membrane or placed in a storage facility.

9. An applicant can comply with this regulation by submitting detailed construction plans for a covered, enclosed, or containerized nonpermanent facility, which indicates, beyond a reasonable doubt, that the accumulative effects of the operation are such that no leachate is generated.

10. In order for a permit to be issued, an embankment or barrier that will serve as a retaining wall must surround the proposed structure. The purpose of the retaining wall is to prohibit inflow or outflow of surface water to or from the site. The retaining wall must be a minimum of ____ feet higher than the surrounding land surface. The lagoon side of the retaining wall and the upper surface shall be protected by an impermeable liner, such as heavy gauge plastic sheeting. The level of fluid in the holding pond or lagoon shall not rise above the ground surface at any time. Failure to maintain the retaining wall and liner will result in revocation of the permit.

11. Wastepiles (stockpiles) within the area of any floodplain covered by a 100-year flood are prohibited.

12. The permit application shall include emergency procedures that will be followed in the event ground water pollution occurs.

These shall include cessation of operation until the necessary corrections are completed.

13. A monitoring well network is required at each disposal site to assure compliance with the discharge permit. The number of wells required, which depends on the size and volume of the wastepile (stockpile) and the subsurface hydrologic characteristics, shall be proposed by the applicant for approval by the agency. The wells shall be located strategically to provide maximum information, but in any case within ____ feet of the wastepile (stockpile) in the downgradient direction.
14. Samples of ground water shall be collected from the monitoring wells at intervals not to exceed six months. Each sample shall be chemically analyzed by a qualified laboratory. The analysis shall include, but not be limited to, identification of specific elements and compounds that are present in the substances stored in the adjacent wastepile (stockpile).
15. In any area where ground water pollution is suspected, due to poor or inadequate operations, or any cause, the agency may require the operator to install additional monitoring wells.
16. If specific elements, chemicals, or compounds known to be present in the wastepile (stockpile) appear in the monitoring well samples at concentrations greater than those in the adjacent ground water before the operation began, the operation shall cease or alternative containment initiated. Within 30 days, the owner or operator of the wastepile (stockpile) shall be required to initiate action, at his own expense, based on plans submitted to and approved by the agency, to return the polluted ground water to

its original chemical, physical, biological, and radiological condition. The renovation work shall be completed within a time deemed appropriate by the agency.

17. If the wastepile (stockpile) is found to be discharging polluting fluid to the ground water, corrective action shall be taken. The agency may require the owner or operator of the wastepile (stockpile) to move it to an area which will meet the requirements of the permit.

18. The permit application shall be accompanied by a performance bond, the amount of which will be determined by the type, concentration, toxicity, and volume of materials to be contained in the wastepile (stockpile).

19. Following abandonment of a wastepile (stockpile) and prior to the release of the bond, the site shall be covered with compacted clay, seeded, and properly drained, and the site inspected by the agency.

20. The bond, if forfeited, will be used to restore the site. In the event of forfeiture of bond, the operator will not be eligible for future permits.

5. ANIMAL FEEDLOTS

Regulations for the Protection of Ground Water

All participating states are required to have a permit system to meet NPDES requirements, which is surface water oriented. The following regulations are mainly for the protection of ground water. A number of states already have adequate administrative controls on animal feedlots and dairy farms. Many of these contain criteria similar to those of the Council of State Government's model Confined Animal Feeding Act. In general, existing rules and regulations prescribe various permit procedures and pay particular attention to pollution of surface water by feedlot runoff. The model act calls for a permit, the application for which requires a considerable amount of information, including the number of livestock and poultry, and maps or aerial photographs showing land use and cultural features, soil characteristics, topography, drainage pattern, depth to the water table, and the location of the proposed confined feedlot relative to receiving waters. It prohibits operations within specified distances of water courses, on floodplains, or within specified distances of parks, private property, or ten or more private residences.

In general, most regulations are written in broad language permitting a fairly wide latitude in interpretation. For example, "the storage of animal feedlot wastes is required to be conducted in such a manner as to prevent the creation of a potential pollution hazard to land, air, or water, and to minimize generation of objectionable odors and the accumulation of insects or other potential disease vectors". Commonly, the soil is required to be relatively impermeable in order to prohibit infiltration of pollutants. Requirements generally call for dikes or curbs of sufficient size to prevent entry of runoff from surrounding storage areas. Generally, regulations prohibit the storage of unprocessed wastes for more than one year. The use of waste-storage facilities as a means for permanent disposal of dead animals is prohibited.

There is no question that infiltration of animal feedlot wastes can cause substantial ground water quality problems, although case histories are not well documented. Infiltration of these wastes can lead to excessive concentrations of nitrate, a health hazard, as well as chloride, organic carbon, and ammonia, in addition to bacteria. Fortunately, the unsaturated zone with its high sorption, filtration, and oxidizing potential, attenuates many, but certainly not all, of the waste substances that are potential ground water pollutants. For example, both nitrate and chloride are highly mobile and are not removed from the ground water. The potential for pollution decreases with increasing depth to the water table, where there is sufficient clay to serve as retention and sorption media, where the water table gradient, especially during pumping, is away from wells, and where there is a great distance between wells and deposits of wastes.

In order to reduce ground water pollution from confined feedlots an application for a permit to construct or modify existing feedlot operations should include, in addition to the normal requirements, data on soil type, permeability, land slope, depth to water table, ground water quality data, and detailed plans for the construction, storage, treatment, and disposal of wastes. Holding ponds or disposal facilities should also be provided in order to collect polluted drainage where large accumulations of manure are stored during winter months but they should be constructed, operated, and maintained in a manner that will not contribute to ground water pollution. In certain hydrologic situations, they should be lined. Furthermore, the operation plan should include alternate storage techniques or methods that would be used to handle overflow amounts and to provide for annual removal of accumulated solids. Regulations that could be used in the vicinity of feedlots, and in particular storage facilities, are found elsewhere in this manual.

These regulations should be supplemented or modified as necessary to conform with current federal regulations in 40 CFR 146 adopted pursuant to the Safe Drinking Water Act (Public Law 93-523) in any state which has been listed by the Administrator of the U. S. Environmental Protection Agency as one for which an underground injection control program is necessary to assure that underground injection will not endanger drinking water sources.

REGULATIONS

1. Every public or private agency or individual that has or intends to have a feedlot for animals, the cumulative number of which exceeds the acceptable limit as established by the responsible State agency, shall obtain a permit.
2. The term of the permit shall be for a period of ____ year(s), subject to renewal.
3. Manure and polluted surface runoff shall be stored, collected, and treated in such a manner so as to minimize infiltration of these wastes to the water table.
4. Where practical, a relatively impermeable surface should form the floor of the feedlot. The soil manure interface should not be disturbed during cleaning operations.
5. Confinement facilities shall have adequate surface drainage to prevent the accumulation of surface water in corrals and feedlots. Embankments shall be constructed to prevent surface runoff into or out of the feedlot.
6. Application of manure and wastewater to croplands shall be at rates that are reasonable for the crop, soil, climate, local situation, management system, and type of manure.

7. The salt in animal rations should be limited to that required to maintain animal health and optimum production.

8. No livestock waste control facility shall be located within ____ feet of any well used for domestic purposes or within ____ feet of any well or wells constituting part of a municipal water supply.

9. All storage areas shall be designed so as to restrict infiltration or other movement of animal wastes to ground waters. The water pollution control facilities shall be operated and maintained so as to prevent ground water pollution and to protect the public health and beneficial uses of the waters of the state.

10. Waste materials removed from retention basins, waste treatment facilities, or confined feeding operations shall be disposed of or stockpiled in a manner that will not contribute to ground water pollution.

11. The permit application shall be accompanied by a proposed plan or alternative plans of action to be followed in the event the proposed facility results in ground water pollution.

12. Samples of ground water, in a number prescribed by the permitting agency, shall be collected for background information at the proposed waste holding pond, lagoon, or collection sump and analyzed by a qualified laboratory prior to issuance of a permit.

13. A monitoring well network shall be established at each waste holding pond or lagoon to assure compliance with the regulations and permit conditions. The number and location of wells shall be prescribed by the agency, based upon the size and volume of the holding pond or lagoon and the subsurface hydrologic characteristics. The wells shall be located strategically to provide

maximum information, but in any case within ____ feet of the holding pond in the regional downgradient direction.

14. Samples of ground water shall be collected from the monitoring wells at regular intervals not to exceed six months. Each sample shall be chemically analyzed by a qualified laboratory.

15. If specific chemicals, elements, or compounds known to be present in the waste in the holding pond, lagoon, or collection sump appear in the monitoring well samples at concentrations significantly exceeding the background concentration in the adjacent ground water, the holding pond, lagoon, or collection sump operation shall cease or alternative containment procedures shall be initiated. The structure shall not be used until the repairs are completed and so certified by the operator. Within 30 days the owner or operator of the structure shall initiate action, at his own expense, to return the polluted ground water to its original chemical, physical, and biological condition. The renovation work shall be completed within a time deemed appropriate by the agency.

16. The agency shall issue a cease and desist order to the owner and operator of the feedlot collection, holding pond, lagoon, or collection sump until the pollution or cause of pollution is eliminated.

17. The operator of a waste holding pond, lagoon, or collection sump used to collect feedlot runoff shall report on the operation, including the size of feedlot, cumulative number of animals, cumulative volume of waste handled, and water quality monitoring data, to the agency twice each year.

18. The permit application shall be accompanied by a performance bond, the amount of which shall be determined by the permitting agency.

19. The bond, if forfeited, will be used to restore the site, or in the case of pollution, to restore the ground water to its original state. In the event of forfeiture of the bond, the operator will not be eligible for future permits.

6. FERTILIZERS

Recommendations for the Protection of Ground Water

The application of fertilizers, primarily for agricultural purposes, has created a threat to ground water quality as well as to surface waters. Until recently, ground water pollution was not as universally recognized, for several reasons. Although relatively soluble, fertilizers are applied on the surface and, because of the economics involved, extremely high concentrations are rare. Thus excess quantities are usually dispersed by surface runoff or absorbed by the soil, leaving a minimum amount penetrating to ground water.

However, several recent discoveries of ground water pollution from fertilizers prove that surface runoff and soil absorption do not always effectively eliminate pollution. An additional problem occurs when fertilizer pollutants infiltrate from surficial streams. For this reason, the cumulative effect of multiple contributors throughout a drainage basin must also be controlled.

To ensure ground water protection, it is recommended that the appropriate agency in each State establish:

1. A network of surface water quality monitoring stations to isolate areas contributing an unacceptable level of fertilizer pollutants (i.e., in excess of National Drinking Water Standards).
2. An adequate network of wells to detect areas where ground water quality is being detrimentally affected by the infiltration of fertilizer pollutants.
3. The right to ban the use of specific chemicals for specific periods of time, or specify maximum loading, as required to restore an acceptable level of water quality.
4. A program for the registration of all fertilizers, or formulations thereof, which are sold within the State.

7. PESTICIDES

Recommendations for the Protection of Ground Water

The Federal Environmental Pesticide Control Act provides for labeling and registration of pesticides; certification of applicators; restriction and regulation of use where deemed necessary; and a national monitoring program, among other provisions. The Act also provides for State operation of the certification and regulation program, if the State prefers.

The organic residues and derivatives of many pesticides are extremely toxic and often very stable. Once these stable organics enter the water supply, whether surface or underground, they tend to recycle in the food chain with an increasing concentration in time. Thus they have enormous capacity for serious environmental, including health, damage.

Ground water supplies, by the nature of their occurrence, are less susceptible to pesticide pollution than surface supplies. Nevertheless, without awareness of the potential pollution problem ground water supplies will be ruined. Once contaminated, cleanup is very difficult, and expensive.

Very little is known about the specific capacity of soils to assimilate known quantities of various pesticides without polluting the underlying ground water. However, it appears at present that the problems of stable organic chemical concentrations become serious in vegetation and adjacent surface water bodies, and often in the food cycle of animals, prior to becoming a problem in the ground water supply. There will undoubtedly be many exceptions to this, but it seems certain that the obvious control point for ground water protection from pesticide pollution is on the surface.

It is recommended that every State adopt a stringent pesticide control plan, in accordance with the federal statute, and add to it the following provisions:

1. Monitoring of ground water in areas of pesticide application for the specific pesticides being applied, and their derivatives.

2. Delineation of areas, by appropriate geologic mapping, where shallow aquifers are recharged; where internal drainage causes ponding, and subsequent infiltration of pesticides that are applied; and areas saturated by high permanent water tables.

3. No pesticides shall be applied within 300 feet of any well, borehole, excavation, septic system (including absorption field), within the confines of any floodplain except by special permit, or within five feet of the highest known seasonal fluctuation of the water table, except for domestic and noncommercial applications where there is no evidence of pollution. The State still reserves the right to ban all applications where pollution has reached critical concentrations, in the judgment of the appropriate agency.

If these provisions are enforced, in conjunction with the other conditions of the law, the damage due to pesticide application will be minimized.

8. SURFACE WATER INFILTRATION

Commentary on Protection of Ground Water

Because the means by which ground water may be protected from infiltration of polluted surface water is to maintain surface water quality standards that are sufficiently high that ground water is not adversely affected, no special regulations are set forth here concerning that subject. The Federal Water Pollution Control Act Amendments of 1972 (P. L. 92-500) and state water pollution control laws and regulations are directed at maintenance of surface water quality standards, and thus as a practical matter at maintenance of ground water quality. It should be borne in mind, however, that surface water quality standards may not be as restrictive as those desirable for the protection of ground water quality, and this should be considered in establishing surface water standards.

9. SEPTIC TANKS

Regulations for the Protection of Ground Water

In the interest of public health, as well as ground water protection, septic tanks and related subsurface sewage disposal systems should not be utilized unless population density or the unavailability of public facilities makes them economically feasible. This rule is generally observed throughout the United States, although there is little uniformity as to the nature of conditions that require the installation of a public system.

Historically, local boards of health, in one form or another, have adopted regulations to protect the public health from the adverse effects of heavy concentrations of septic systems and faulty design and construction. These have often taken the form of minimum lot sizes and spacing requirements and minimum design standards or individual installations.

Fortuitously, these health regulations have served, in many instances, to protect ground water supplies. Failures have generally been related to lack of understanding of local geological and ground water conditions.

Particularly, problems can be anticipated in areas where soils are thin and are directly over fissured, open rock such as some limestone, granite, and sandstone formations. In general it can be noted that problems develop at both ends of the spectrum -- in tight, impermeable soils where proper infiltration cannot occur, and at the other extreme in loose, highly permeable conditions where the soil lacks adequate absorptive capacity to provide treatment of the sewage material.

For these reasons the following regulations are intended to be directed toward reinforcement of current good practices in septic tank design and construction.

In addition, it is here proposed that each state shall develop and utilize sufficient soils and geologic data to make it possible for local governing bodies to provide sound local practices, both for septic tank design and use, and for septic sludge disposal, where no treatment facilities are possible.

In any area where the density of homes exceeds 100 units per square mile, and no public sewers are provided, the appropriate agency should develop and operate a monitoring network sufficient to determine whether or not the aggregate effect of all subsurface sewage disposal systems is having an adverse effect upon ground water quality. If ground water quality is deteriorating from this cause, the agency should have the authority to stop all further construction in the area until a public sewer system or equivalent alternative can be provided.

These regulations are not intended to cover all aspects of subsurface disposal systems, but only those aspects important to the protection of ground water quality standards.

These regulations should be supplemented or modified as necessary to conform with current federal regulations in 40 CFR 146 adopted pursuant to the Safe Drinking Water Act (Public Law 93-523) in any state which has been listed by the Administrator of the U. S. Environmental Protection Agency as one for which an underground injection control program is necessary to assure that underground injection will not endanger drinking water sources.

REGULATIONS

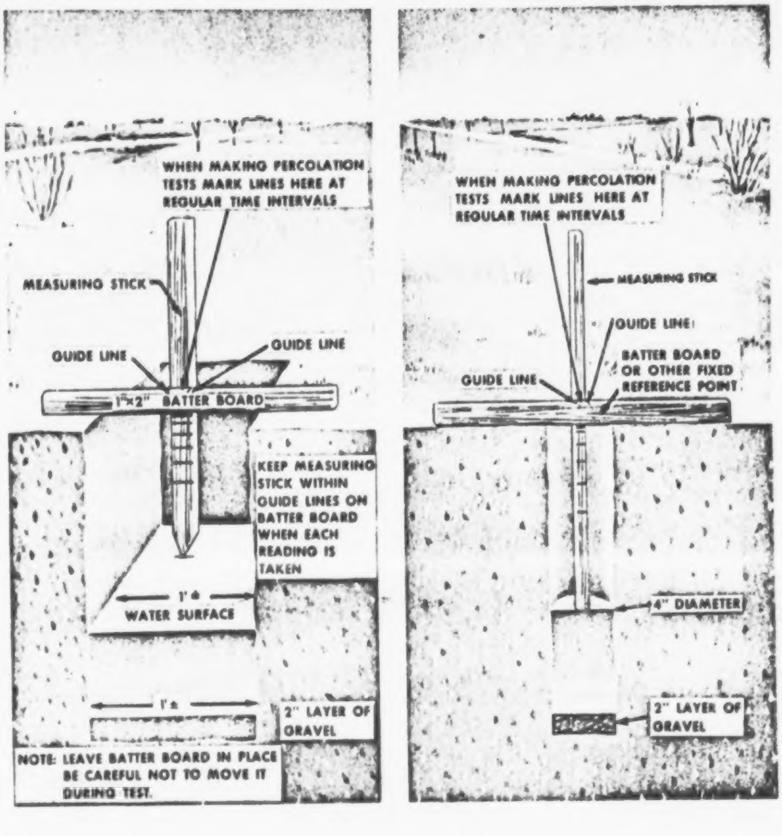
1. The construction and use of any subsurface sewage disposal system is prohibited if such construction or use results in the significant deterioration of ground water quality.
2. Every public or private agency or individual using or intending to utilize any type of subsurface sewage disposal system shall apply for a permit from the agency. A permit application shall include the following information:
   (a) accurate, detailed location of the proposed system,
   (b) percolation test data, in accordance with following procedures for percolation tests,
   (c) design details of both the spetic tank and soil absorption system in accordance with minimum design requirements, as follows in these regulations,
   (d) maximum seasonal elevation of ground water, as certified by a qualified ground water geologist, or the appropriate geological agency of the state.
3. Septic tank installers and pumpers (cleaners) shall be licensed by the appropriate agency. No septic tank shall be installed without the required permit.
4. Multi-housing, commercial, and institutional applications shall be evaluated and permitted or rejected upon the basis of

individual design. In all instances the design shall at least meet the comparable minimum standards prescribed for individual or single family homes. No permit shall be issued where ground water quality will be adversely affected.

5. The maximum seasonal elevation of the ground water table shall be at least 4 feet below the lowest portion of the proposed soil absorption system.
6. Seepage pits and cesspools are not permitted.
7. Percolation tests shall be performed in accordance with procedures developed at Robert A. Taft Sanitary Engineering Center, as follows: (Source: U.S. Dept. of Health, Education, and Welfare, "Manual of Septic Tank Practice", 1967)
    - A. Number and location of tests. - Six or more tests shall be made in separate test holes spaced uniformly over the proposed absorption field site.
    - B. Type of test hole. - Dig or bore a hole, with horizontal dimensions of from 4 to 12 inches and vertical sides to the depth of the proposed absorption trench. In order to save time, labor,and volume of water required per test, the holes can be bored with a 4 inch auger. (See Figure 1)
    - C. Preparation of test hole. - Carefully scratch the bottom and sides of the hole with a knife blade or sharp pointed instrument, in order to remove any smeared soil surfaces and to provide a natural soil interface into which water may percolate. Remove all loose material from the hole. Add two inches of coarse sand or fine gravel to protect the bottom from scouring and sediment.

Figure 1.

METHODS OF MAKING PERCOLATION TESTS


WHEN MAKING PERCOLATION TESTS MARK LINES HERE AT REGULAR TIME INTERVALS
MEASURING STICK
GUIDE LINE
GUIDE LINE
1"×2" BATTER BOARD
KEEP MEASURING STICK WITHIN GUIDE LINES ON BATTER BOARD WHEN EACH READING IS TAKEN
1'±
WATER SURFACE
1'±
2" LAYER OF GRAVEL
NOTE: LEAVE BATTER BOARD IN PLACE BE CAREFUL NOT TO MOVE IT DURING TEST.
WHEN MAKING PERCOLATION TESTS MARK LINES HERE AT REGULAR TIME INTERVALS
MEASURING STICK
GUIDE LINE
BATTER BOARD OR OTHER FIXED REFERENCE POINT
GUIDE LINE
4" DIAMETER
2" LAYER OF GRAVEL

D. Saturation and swelling of the soil. - It is important to distinguish between saturation and swelling. Saturation means that the void spaces between soil particles are full of water. This can be accomplished in a short period of time. Swelling is caused by intrusion of water into the individual soil particle. This is a slow process, especially in clay-type soil, and is the reason for requiring a prolonged soaking period.

In the conduct of the test, carefully fill the hole with clear water to a minimum depth of 12 inches over the gravel. In most soils, it is necessary to refill the hole by supplying a surplus reservoir of water, possibly by means of an automatic syphon, to keep water in the hole for at least four hours and perferably overnight. Determine the percolation rate 24 hours after water is first added to the hole. This procedure is to insure that the soil is given ample opportunity to swell and to approach the condition it will be in during the wettest season of the year. Thus, the test will give comparable results in the same soil, whether made in a dry or in a wet season. In sandy soils containing little or no clay, the swelling procedure is not essential, and the test may be made after the water from one filling of the hole has seeped away.

8. Septic tanks shall be of the minimum capacities indicated in Table 2. The design of the septic tank shall be in accordance

Figure 2.

SUBSURFACE DISPOSAL FIELD

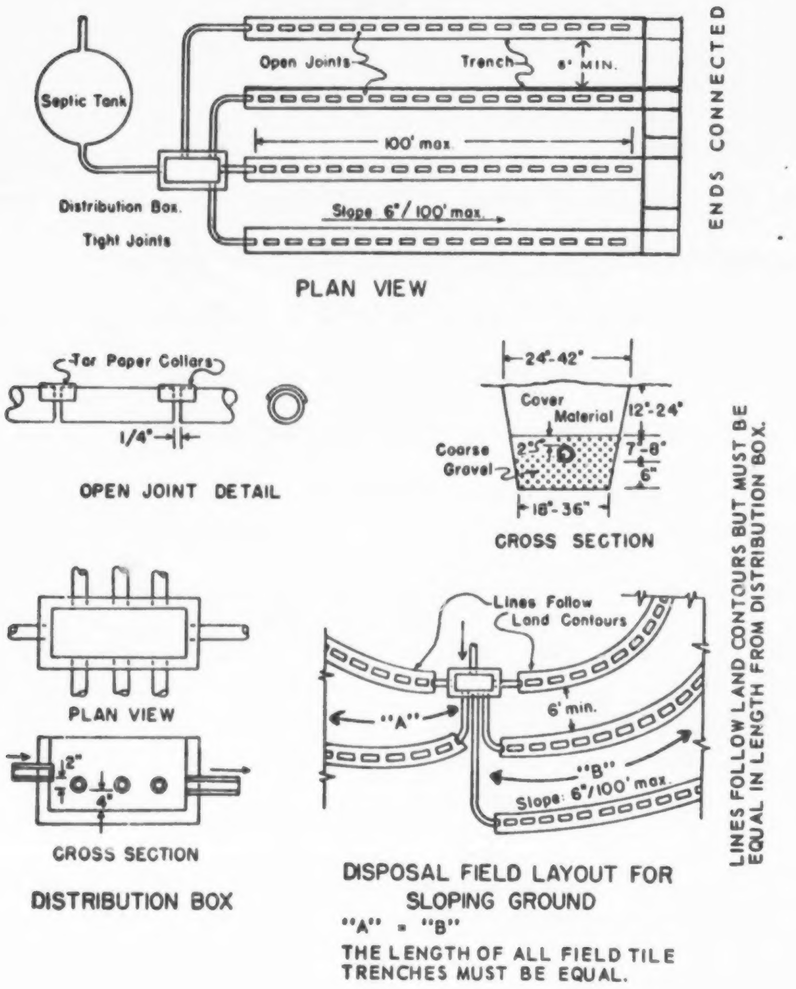

Septic Tank
Open Joints
Trench
6' MIN.
100' max.
Distribution Box.
Tight Joints
Slope 6"/100' max.
ENDS CONNECTED
PLAN VIEW
Tar Paper Collars
1/4"
OPEN JOINT DETAIL
24"-42"
Cover Material
12"-24"
Coarse Gravel
2"
7"-8"
6"
18"-36"
CROSS SECTION
PLAN VIEW
2"
4"
CROSS SECTION
DISTRIBUTION BOX
Lines Follow Land Contours
"A"
6' min.
"B"
Slope: 6"/100' max.
DISPOSAL FIELD LAYOUT FOR SLOPING GROUND
"A" = "B"
THE LENGTH OF ALL FIELD TILE TRENCHES MUST BE EQUAL.
LINES FOLLOW LAND CONTOURS BUT MUST BE EQUAL IN LENGTH FROM DISTRIBUTION BOX.

TABLE 1.

Absorption-Area Requirements For Individual Residences (a)

[Provides for garbage grinder and automatic clothes washing machines]

Percolation rate (time required for water to fall one inch, in minutes)	Required absorption area, in sq. ft. per bedroom (b), standard trench (c), seepage beds (c), and seepage pits (d)	Percolation rate (time required for water to fall one inch, in minutes)	Required absorption area in sq. ft. per bedroom (b), standard trench (c), and seepage beds (c),
1 or less	70	10	165
2	85	15	190
3	100	30 (e)	250
4	115	45 (e)	300
5	125	60 (e), (f)	330

(a) It is desirable to provide sufficient land area for entire new absorption system needed in future.[1]

(b) In every case sufficient land area should be provided for the number of bedrooms (minimum of 2) that can be reasonably anticipated, including the unfinished space available for conversion as additional bedrooms.

(c) Absorption area is figured as trench-bottom area and includes a statistical allowance for the vertical side wall area.

(d) Absorption area for seepage pits is figured as effective side wall area beneath the inlet.

(e) Unsuitable for absorption systems if over 60.

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[1] Section 5.1(b) (2) (A) Page 20 of Recommended State Legislation and Regulations: Urban Water Supply and Sewerage Systems Act and Regulations, Water Well Construction and Pump Installation Act and Regulations, Individual Sewerage Disposal Systems Act and Regulations. U.S.D.H.E.W., Public Health Service, July 1965.

with the design recommendations of the Manual of Septic Tank Practice, pages 29 to 40.

9. Subsurface seepage fields (leach fields or absorption trenches) if found to be applicable by percolation test, should be designed and constructed in accordance with Tables 1, 2, 3, and Figure 2, and the following items A through E.

A. Disposal Field. The layout, size, and minimum spacing requirements for disposal fields should conform to those given in Figure 2 and Table 4.

B. Disposal Trenches. Disposal trenches should be designed and constructed on the basis of the required effective percolation area determined by percolation tests and Table 1. The bottom of the trenches should be at least 4 feet above the normal ground water level.

C. Absorption Lines. Absorption lines should be constructed of farm tile, perforated tile, bituminized fiber pipe, asbestos cement or semirigid plastic pipe with suitable perforations. Farm tile should be laid with open joints. The tile sections should be spaced not more than 1/4 inch apart, and the upper half of the joint should be protected by asphalt treated paper while the tile is being covered.

D. Bedding Material. The bedding material should extend the full width of the trench and should be not less than six inches deep beneath the bottom of the tile. After the tile has been laid, the bedding material should be brought up to a level of 2 inches above the top of the tile. The bedding material should be washed gravel, crushed stone, slag, or clean bank-run gravel ranging in

TABLE 2.

MINIMUM CAPACITIES FOR SEPTIC TANKS SERVING AN INDIVIDUAL DWELLING

Number of Bed-rooms	Maximum Number of Persons Served	Liquid Cap. of Tank (No auto. washing machine no garb. grinder)	Liquid Cap. of Tank (with auto. washing machine only)	Liquid Cap. of Tank (with garb. grinder only)	Liquid Cap. of Tank (with both auto. washing mach. & garb. grinder)
	PERSONS	GALLONS	GALLONS	GALLONS	GALLONS
2	4	750	938	1125	1313
3	6	900	1125	1350	1575
4	8	1200	1500	1800	2100
5	10	1500	1875	2250	2625
6	12	1800	2250	2700	3150
7	15	2250	2813	3375	3938

NOTE: The minimum allowable liquid depth shall be 4 feet. Tanks in excess of 1200 gallon capacity shall be designed on the basis of 1½ times the daily flow of 100 gallons per person per day up to 1500 gallons per day. Flows greater than 1500 gallon per day the minimum effective tank capacity should equal 1500 gallons plus 75% of daily sewage flow. This formula $V = 1500 + .75Q$ may be used. V = Volume and Q = Daily sewage flow in gallons.

TABLE 3.

MINIMUM STANDARDS FOR DISPOSAL FIELD CONSTRUCTION

Disposal-field construction	Minimum Standard
Lines per field, minimum number	2
Individual lines, maximum length	100 ft.
Trench bottom, minimum width	18 in.
Trench bottom, maximum width	36 in.
Field tile, minimum diameter	4 in.
Field-tile lines, maximum slope	6 in. in 100 ft.
Field trenches, minimum separation	(1)
Effective absorption area, minimum per dwelling unit	(2) 200 sq. ft.

(1) See Table V
(2) See Table III

All lines from distribution box should be equal.

TABLE 4.

SIZE AND SPACING FOR DISPOSAL FIELDS

Width of Trench at Bottom	Recommended Depth of Trench	Spacing Tile Lines (1)	Effective Absorption Area per Lineal Foot of Trench
Inches	Inches	Feet	Square Feet
18	18 to 30	6.0	1.5
24	18 to 30	6.0	2.0
30	18 to 36	7.6	2.5
36	24 to 36	9.0	3.0

(1) A greater spacing is desirable where available area permits.

size from 1/2 to 2-1/2 inches. The bedding material should be covered by a 2-inch layer of pea gravel or straw to support the backfill as the laying of the tile drain proceeds. (Plastic should not be used as a barrier between the seepage line and the earth fill for the trench.)

E. Distribution Box. A distribution box should be provided to receive the effluent from the septic tank to assure equal distribution to each individual line of the disposal field, as shown in Figure 3, in accordance with the following items:

(1) Connection. The distribution box should be connected to the septic tank by a watertight sewer line and be located at the upper end of the disposal field.

(2) Invert Level. The invert of the inlet pipe should be located 6 inches above the bottom of the box. The invert of the

outlets to each distribution line should be located 4 inches above the bottom of the box and set at the same elevation.

(3) Inspection. The sides of the box should extend to within a short distance of the ground surface to permit inspection. The box should be kept to the minimum size necessary to accommodate the inlet and outlets.

10. In areas having dense soil with a percolation test time greater than 60 minutes which precludes the use of subsurface absorption lines, sand filters may be used. The filters should be designed in accordance with Figure 3, and the following sub-paragraphs A through H.

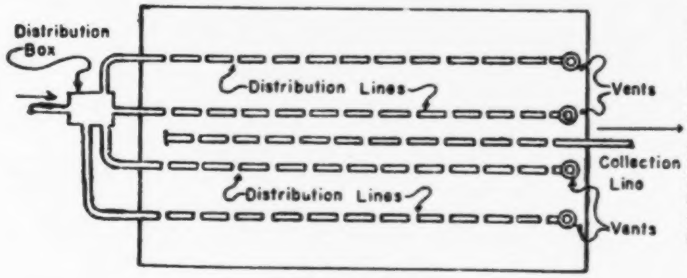
   A. Size. The size should be such to provide 100 square feet of filter area per person served, or 200 square feet of filter area per bedroom. In systems serving an automatic washing machine, the size should be increased to provide 250 square feet of filter area per bedroom. It is recommended that the size be based on a filter 20 feet square for a two-bedroom home, with an additional 10 feet of length added for each additional bedroom. Enginners should design larger sand filters on the bases of one gallon/square foot.

   B. Minimum Filtering Depth. The minimum filtering (sand) depth should be 24 inches.

   C. Cover Material and Depth. The filter may be covered with a maximum depth of 12 inches of porous soil or medium to coarse gravel.

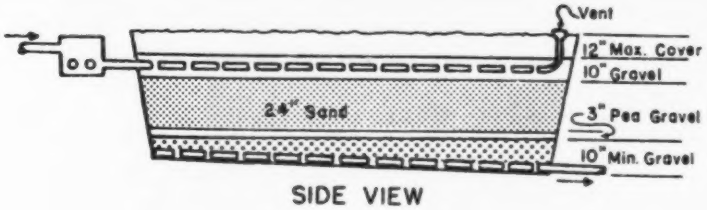
FIGURE 3.

BURIED SAND FILTER

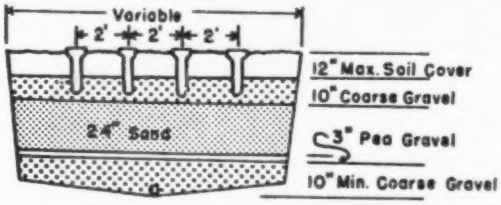

Distribution Box
Distribution Lines
Distribution Lines
Vents
Collection Line
Vents

CHLORINE CONTACT BASINS MUST HAVE A 15 MINUTE DETENTION TIME.

PLAN VIEW


Vent
12" Max. Cover
10" Gravel
24" Sand
3" Pea Gravel
10" Min. Gravel

SIDE VIEW


Variable
2'
2'
2'
12" Max. Soil Cover
10" Coarse Gravel
24" Sand
3" Pea Gravel
10" Min. Coarse Gravel

END VIEW

D. Filter Media. The filter media (sand) should have an effective size of 0.6 to 1.0 millimeters and a uniformity coefficient of less than 3.5. It should be washed and free from clay or silt.

NOTE: The following buried sand filter design can be expected to function properly only if it is installed in exact accordance with design criteria. The effective size and uniformity coefficient of the sand are of the utmost importance. Mortar sand and most natural (pitrun) sands are not satisfactory and their use will result in an early failure of the filter. If antural sand having the correct specifications is not available, graded sand should be used. No sand should be used in the basence of a sieve analysis report; sand effective size should be 0.6 to 1.0 mm.

E. Distribution and Collection Lines. The distribution and collection lines should conform to the requirements for absorption lines as given in paragraph C in the seepage field section. The distribution lines should have a slope of two inches per 100 feet and should be spaced two feet apart, center-to-center. The collection lines should have a slope of six inches per 100 feet and one collection line should be provided for each 10 feet of width, or fraction thereof. The lower end of the distribution lines should be vented as required in paragraph G, and the upper end of the collection lines should be completely plugged. Automatic siphons should be considered for installations serving more than four bedrooms.

F. Bedding Material. The bedding material for the distribution and collection lines should be placed and should consist of washed gravel, washed crushed stone, or slag. The coarse gravel may range in size from 1/4 to 1-1/2 inches in diameter. The collection lines should be laid directly on the cut, without placing gravel beneath the line.

G. Venting. Vents should be placed on the downstream end of each of the distribution lines. The vents should extend to, or slightly above the ground surface and the outlet should be screened with 1/4 inch mesh screen.

H. Drainage. Adequate drainage must be provided to prevent ponding of surface water above the filter, and adequate drainage must also be available to insure free drainage of the effluent from the filter.

11. Septic tank sludges shall be disposed of by hauling to regional sewage treatment facility whenever this is possible.

12. Septic tank sludges, when no treatment facilities are available, may be disposed by sludge spreading or spraying, in permitted sites only, by licensed pumpers.

Permits for sludge spreading or spraying sites shall be obtained as defined under regulations for wastewater sludge disposal. In addition to these requirements, the permit application shall state procedures to be utilized for:

(a) cropping the land, and disposal of crops,

(b) preventing public nuisance and health hazards due to the presence of the disposal site,

(c) the capability of the soil to utilize nitrogen without excessive concentrations. Attention is directed to "guidelines" of the State of Maine which note that 37,000 gallons of sludge contains 300 pounds of nitrogen, which is the maximum application to a moderately well drained loamy soil.

It is recognized that septic tank sludges are very liquid, malodorous, unhealthful materials. If at all possible they should be directed to a sewage treatment plant. Under no circumstances, except full treatment, should they be directly disposed in landfill, compost, subsurface injection, or land reclamation outside of a licensed site.

10. STORAGE AND TRANSMISSION FACILITIES

Regulations for the Protection of Ground Water

Serious instances of ground water pollution occur when transmission or storage facilities are allowed to discharge onto or into the ground. Among the most striking, yet insidious, examples of pollution from this source are leakage from sanitary sewers, and leakage from buried gasoline tanks for service stations.

These are typical examples of a wide range of related hazards including leakage from surface storage tanks, transmission lines, underground storage tanks and pipelines for many types of chemicals, biological products, and petrochemicals. As a result of the variety and complexity of this problem it is not practical to attempt to specifically regulate all occurrences. As a consequence these regulations are directed at proper design, periodic inspection, and ground water quality monitoring in certain instances.

Since the usual occurrence of pollution from this source would be unplanned, or accidental, the correction of problems that occur will be as indicated under "Accidental Spills."

These regulations should be supplemented or modified as necessary to conform with current federal regulations in 40 CFR 146 adopted pursuant to the Safe Drinking Water Act (Public Law 93-523) in any state which has been listed by the Administrator of the U. S. Environmental Protection Agency as one for which an underground injection control program is necessary to assure that underground injection will not endanger drinking water sources.

REGULATIONS

1. Every storage and transmission facility except gravity sewers shall be designed and constructed to withstand all shocks, forces, and pressures to which it is expected to be subjected plus a safety factor of at least 100 per cent.
2. Gravity sanitary sewers shall meet the current prescribed standard for exfiltration and infiltration. All sanitary sewers shall be inspected or tested for leakage at least once every five years.
3. All storage tanks and transmission facilities shall be pressure tested when installed, and at intervals thereafter not to exceed once every five years. Hydrostatic pressure testing shall be conducted at 150 per cent of the design operating pressure.

In the event of a leak, the facility shall be removed from service until repairs are made.

4. Records of every inspection or test shall be maintained for periodic review by authorized State personnel. The record shall include the date of the inspection, equipment used, results obtained, and the sworn, notarized statement of the person making the inspection as to the accuracy of the report. Inspectors shall be licensed by the State.
5. Surface storage and transmission facilities shall be visually inspected for leaks annually. All surface storage tanks shall be surrounded by an impermeable base and dike enclosing sufficient volume to contain at least the entire storage capacity of the tank. Shut-off valves for the transmission line supplying each tank shall be located in an accessible location, adjacent to each tank.
6. In the event of a spill the procedures for immediate reporting, cleaning-up, etc., all as detailed in the handling of "accidental spills," shall be observed.
7. In any area where ground water pollution is suspected, due to poor operations, frequency of spills, or any cause, the supervising State agency may require the operator of the storage or transmission facility to install monitoring wells to check ground water quality.

If the agency determines from the monitoring wells that the ground water quality is being adversely affected, a bond and liability insurance may be required of the operator, as specified in the statutes.

If tests confirm that ground water is being affected, in excess of National Drinking Water Standards, the use of the facility shall be discontinued until complete repairs are made. Immmediate steps shall also be taken by the operator to restore the ground water to an acceptable quality. This restoration must be completed within six months, or the State will undertake the restoration at the expense of the operator. This time may be extended by the State only if the operator is vigorously attempting to perform the restoration and additional time is required by circumstances beyond his control.

11. ACCIDENTAL SPILLS

Regulations for the Protection of Ground Water

Accidental spills of hazardous materials, whether toxic or merely unpleasant, present an imminent possibility of seriously polluting both surface and ground water supplies. Since they are "accidental", no amount of preplanning will completely eliminate these problems.

However, a system which makes those involved responsible for correcting the resultant damage can do two things. It can reduce the number of "accidents", and it can minimize the damage done to the public as a consequence of accidental spills.

REGULATIONS

1. Whenever, because of an accident or other activity or incident, any toxic or taste- and odor-producing substance, or any other hazardous substance which is discharged into waters or is so placed that it might discharge, flow, be washed, or fall into them and which, if in contact with such waters, would endanger their use or in any way adversely change the quality of that water, it shall be the responsibility of the person or establishment owning or in charge of such substance or the facility or vehicle from which it was discharged, to immediately notify the proper State agency, by telephone, of the location and nature of such substance, and where reasonably possible to do so, notify all potential users of the waters.
2. In addition to the notices set forth in Regulation 1, such person or establishment shall immediately take or cause to be taken all necessary steps to prevent injury to property and to users of said waters, and to protect said waters from pollution or a danger of pollution; and shall within 15 days of the incident remove from the ground and from the affected waters, to the extent required by the State agency, the residual substances contained thereon or therein.
3. Any oil or oil products; radioactive materials; materials transported in large commercial quantities which are very soluble acids or bases, cause abnormal growth of organs or organisms, or are highly biodegradable, exerting a severe oxygen demand; biologically accumulative poisons; lethal substances; or any other

substance which might cause water pollution or in any way adversely affect water quality shall be considered hazardous to water quality.

4. The State agency shall provide a continuous operator service to handle emergency telephone calls. Telephone numbers for pertinent State agencies are listed as follows:

____

____

____

5. Should additional information or notification be necessary, regional and national emergency telephone numbers with continuous service are listed as follow:

HAZARDOUS MATERIALS	EPA REGIONAL HEADQUARTERS
Boston, Mass.	(617) 223-7265
New York, N. Y.	(201) 548-8730
Philadelphia, Pa.	(215) 597-9898
Atlanta, Ga.	(404) 526-5062
Chicago, Ill.	(312) 353-6188
Dallas, Texas	(214) 749-3840
Kansas City, Mo.	(816) 374-3778
Denver, Colo.	(303) 837-3880
San Francisco, Cal.	(415) 558-6254
Seattle, Wash.	(206) 442-4343

FDA POISON CONTROL CENTER

(202) 963-7512

CHEMTREC (Chemical Transportation Emergency Center)

(800) 424-9300

Except Alaska, Hawaii and Washington, D.C.

(202) 483-7616

6. All persons and establishments engaged in an activity which includes the impoundment, production, processing, transportation, storage, use, application, or disposal of polluting substances shall take all necessary measures to prevent such substances from reaching natural waters, directly or indirectly, through accident, carelessness, maliciousness, hazards of weather, or from any other cause.
7. Any person or establishment engaged or planning to engage in any of the activities described in Regulation 6 shall submit to the activity and all substances involved, the preventative measures which are taken or will be taken to comply with Regulation 6, the remedial actions to be initiated in case of accidents, and such other information as the State agency may require.
8. Compliance with these regulations does not affect the civil or criminal liability to which said person or establishment may be subject as a result of such activities or incidents.

12. HIGHWAY SALTING

Regulations for the Protection of Ground Water

Serious problems have resulted in areas where chemicals have been used in excessive quantities for the control of ice and snow on highways. These problems cannot be entirely eliminated without endangering the public safety. The following regulations will serve to assist in minimizing the pollution problem.

A specific plan shall be developed for ground water problems caused by ice and snow control on streets and highways. This plan shall include the keeping of specific records on the quantities and rate, and frequency of application of chemicals to specific sections of roads and streets.

As an alternative to the following each state may wish to adopt a monitoring program for chemical contamination as part of their Section 303E Continuing Planning Process.

REGULATIONS

1. Whenever possible inert abrasives, such as sand, shall be used in place of chemicals. Chemical quantities shall be the minimum required for safety.
2. In areas of heavy application of chemicals, shallow monitoring wells shall be established within 50 feet of the right of way. Samples shall be collected from each monitoring well and analyzed for chemical content at least quarterly.

   Sufficient monitoring wells shall be utilized to define the area where the application of chemicals is occurring. The number, design, and location of monitoring wells shall be determined as part of the plan, and shall be determined by qualified geological personnel, who shall also provide for record keeping of salt loading as required.

3. Where unavoidable chemical pollution occurs the plan shall provide for corrective action to be undertaken. This action may include one or more of the following, or any other activity that proves effective:
   (a) cessation of application of chemicals,
   (b) drainage control to intercept chemicals prior to contact with the ground water,
   (c) pumpage to reduce chemical level,
   (d) injection of unpolluted water to flush and dilute chemicals.
4. If it becomes evident that pollution of ground water is occurring as a consequence of highway de-icing, the responsible agency shall provide for full public notification of the problem, and information as to the proposed course of corrective action.

   This notification shall utilize at least three locally prominent newspapers, plus such other local agencies as are necessary to make the public aware of the problem.

13. AIR POLLUTION

Commentary on Protection of Ground Water

Ground water quality can be affected by air pollution because it is in effect a form of land spreading of waste -- particulate matter falls to the ground and if water soluble and in sufficient concentrations, it may find its way into adjacent ground water supplies. Regulations concerning air pollution control are not presented here because there is no ground water aspect to such regulations that is separate from regulation for any other purpose. The states have enacted statutes and adopted regulations to control air pollution, primarily in response to the 1970 Amendments to the Federal Clean Air Act, which required states to meet federal standards. The Council of State Governments proposed a model State Air Pollution Control Act in 1973.

14. DRAINAGE WELLS AND SUMPS

Regulations for the Protection of Ground Water

Drainage wells are commonly used to drain wet areas, such as swamps and potholes, by allowing the excess water to flow into underground storage. In some regions the word "sump" is used synonymously with "drainage well". Elsewhere, however, the term "sump" is used to describe a dry excavation used to collect spilled materials, such as hydrocarbons, as well as surface runoff. They are also called "dry wells."

It is probably administratively impossible to regulate domestic sumps, which contribute but slightly to ground water pollution. At industrial and commercial sites, however, sumps may provide a sizeable quantity and wide variety of pollutants.

A realistic means of controlling ground water pollution from drainage wells and sumps is by use of permits, bonds, and fines, and making the operator liable for damages. Local geohydrologic conditions, in conjunction with the type and quantities of wastes that will or may infiltrate, will dictate the feasibility of permitting sumps and drainage wells in selected areas.

The collection of storm runoff waters in drainage wells and sumps presents a special problem that must be examined in the light of the local hydrologic situation and needs. During the early part of a storm, the runoff is generally grossly polluted, but it improves in quality with time as the wastes are flushed away and diluted. In many areas it is advantageous to collect the runoff in various types of structures for two purposes: (1) to reduce the potential for flooding, and (2) to provide ground water recharge. Whether the early runoff should be allowed to infiltrate is a question that must be carefully evaluated. In many situations, it is much more advantageous to allow it to infiltrate, despite its chemical and biological nature, than it is to waste it.

These regulations should be supplemented or modified as necessary to conform with current federal regulations in 40 CFR 146 adopted pursuant to the Safe Drinking Water Act (Public Law 93-523) in any state which has been listed by the Administrator of the U. S. Environmental Protection Agency as one for which an underground injection control program is necessary to assure that underground injection will not endanger drinking water sources.

REGULATIONS

1. The construction and use of wells (exclusive of storm runoff collection wells) for drainage of surface water from lands into the ground shall be prohibited if the chemical, physical, biological, or radiological properties of the surface water would cause the ground water quality to exceed National Drinking Water Standards.

   (Sec. 1421 (d) (2) of the Safe Drinking Water Act would prohibit injection that "endangers drinking water sources" -- i.e. that results in the presence of a contaminant in underground water which supplies or can reasonably be expected to supply any public water system, if "the presence of such contaminant may result in such system's not complying with any national primary drinking water regulation or may otherwise adversely affect the health of persons.")

2. Every public or private agency or individual using or intending

to use, construct, modify, or maintain a drainage well shall apply for a permit from the agency. The permit application shall contain a map or aerial photograph of the site at a scale of 1:24,000; justification for the drainage well; location, well diameter, proposed depth, depth and length of casing, and depth and length of screen or perforations; depth of the receiving aquifer, its thickness, permeability, and water level; the chemical, physical and biological quality of the receiving water and of the waters to be discharged; the quantity to be discharged and its seasonal variation in quantity and quality; and the location of all water supply wells and springs within a ____ mile radius of the drainage well.

3. The construction and use of sumps for collection and disposal of any type of liquid, semi-liquid, or water soluble solid material, exclusive of domestic or household use (and storm runoff), is prohibited unless a valid permit has been issued by the agency.

4. Every public or private agency or individual using or intending to use, construct, modify, or maintain a sump shall apply for a permit from the agency. The permit application shall contain a map or aerial photograph of the site at a scale of 1:24,000; justification for the sump; location, sump diameter, proposed depth, and depth and length of casing; depth of receiving strata, receiving strata rock type, thickness, permeability, and water level; the chemical, physical and biological quality of water in the receiving strata; the types and the chemical, physical, and biologic properties of all materials that might be flushed into the sump; and the location

of all water supply wells and springs within a ____ mile radius of the sump.

5. The term of a permit for a drainage well or sump shall be ____ year(s), subject to renewal.

6. Samples of ground water in a number prescribed by the permitting agency shall be collected for background information at the proposed (drainage well) (sump) site and analyzed chemically by a qualified laboratory prior to issuance of a permit. The analysis shall include, but not be limited to, identification of specific elements, chemicals, and compounds that are present or presumed to be present in the water or water soluble material that may flow into the structure.

7. No permit shall be issued that will result in the indigenous ground water quality exceeding the chemical levels for raw or untreated drinking water supply sources as specified in the National Drinking Water Standards, including future additions and modifications.

8. The permit application shall be accompanied by a proposed plan or alternative plans of action to be followed in the event the proposed facility results in ground water pollution.

9. A monitoring well network may be required at each (drainage well) (sump). The number and location of monitoring wells shall be prescribed by the agency, based upon the diameter and storage volume of the (drainage well) (sump), and the subsurface hydrologic characteristics. The wells shall be located strategically to provide maximum information, but in any case within ____

feet of the (drainage well) (sump) in the regional downgradient direction.

10. If monitoring wells are required by the agency, samples of ground water shall be collected from them at regular intervals, not to exceed six months. Each sample shall be chemically analyzed by a qualified laboratory. The analysis shall include, but not be limited to, identification of specific chemicals, elements, and compounds that are present or presumed to be present in the water or water soluble material that may flow into the (drainage well) (sump) as specified in the permit procedure.

11. If specific chemicals, elements, or compounds known to be present or assumed to be present in the water or water soluble material that flows into the (drainage well) (sump) appear in the monitorint well samples at concentrations significantly exceeding the background concentration in the adjacent ground water, the operation shall cease or alternative containment procedures shall be initiated. Within 30 days the owner or operator of the structure shall be required to initiate action at his own expense, to return the polluted ground water to its original chemical, physical, and biological and radiological condition. The renovation work shall be completed within a time deemed appropriate by the agency.

12. The agency shall order the operator of the (drainage well) (sump) to cease and desist until the pollution or cause of pollution is eliminated.

13. Should the (drainage well) (sump) be the cause of any pollution of the ground water or significantly alter the natural quality of the ground water in such a manner to damage another ground water

user, the owner and operator of the (drainage well) (sump) shall be liable to the injured user for damages.

14. The operator of the (drainage well) (sump) shall make an annual report to the agency on the condition of the facility.

15. The permit application shall be accompanied by a performance bond, the amount of which is based upon the (drainage well) (sump) diameter, the chemical, physical, biologic and radiologic quality, and the volume of solutions that will or may flow into the structure.

16. The bond, if forfeited, will be used to restore the site, or, in the case of pollution, to restore the ground water to its original state. In the event of forfeiture of bond, the operator will not be eligible for future permits.

17. When the use of a (drainage well) (sump) has been terminated, it shall be abandoned according to aquifer sealing criteria contained in Recommended Water Well Construction Standards (see Water Supply Wells, below).

18. Following abandonment of the (drainage well) (sump) and its subsequent plugging, and prior to the release of the bond, the site shall be inspected and approved by the agency.

15. ARTIFICIAL RECHARGE

Regulations for the Protection of Ground Water

As local ground water overdrafts and sea water intrusion continue to occur throughout the country, artificial recharge techniques will become more widespread. The use of artificial recharge techniques are to be encouraged as long as they are accomplished in a sound technological manner, coupled with adequate water management programs.

The most important aspects of artificial recharge that need to be considered are (1) control and monitoring of the chemical, biological, and radiologic properties of the recharging water in order to insure that it does not lead to pollution or impairment of the ground water reservoir, and (2) control and monitoring of the water level so that adverse effects do not occur.

Artificial recharge facilities can best be managed by means of permits. The permit should be issued on the basis of the engineering design and the quality of the receiving water, the water to be recharged, and a mixture of the two. It might also be necessary to predict the chemical reactions that could occur between the recharging water, the aquifer framework, and the aquifer fluids. Since surface water is commonly used as a source of recharge water, information concerning the seasonal variations in water quality must be available.

The water level may rise significantly in the vicinity of an area being artificially recharged. In many situations, this rise would need to be carefully monitored and controlled in order to reduce adverse effects that might occur, such as the formation of new springs, seeps, flowing wells, and flooded foundations in the vicinity of the site. Furthermore, a water level rise could cause polluted ground water, if any existed, to flow in a new direction leading to deteriorating quality in affected wells.

These regulations should be supplemented or modified as necessary to conform with current federal regulations in 40 CFR 146 adopted pursuant to the Safe Drinking Water Act (Public Law 93-523) in any state which has been listed by the Administrator of the U. S. Environmental Protection Agency as one for which an underground injection control program is necessary to assure that underground injection will not endanger drinking water sources.

REGULATIONS

1. Every public or private agency or individual shall obtain a permit prior to engaging in artificial ground water recharge. The application for a permit shall include a map or aerial photograph of the site at a scale of 1:24,000, and describe the techniques and methods of artificial recharge, the amount of water proposed to be recharged, source of water to be recharged, type of treatment of recharge water proposed, the purpose of the artificial recharge, the period of operation of the facility, chemical, biological, and physical data concerning the quality of the water to be artificially recharged, and the existing quality of the ground water. The location of all wells within a ____ mile radius shall be shown on a map. The application shall include a report of reactions that may be anticipated due to mixing of the natural and artificially recharged water. The mixed waters shall be of acceptable quality for the use intended but they shall not exceed National Drinking Water Standards if the native ground water is potable. All information used to determine the technical feasibility of artificial recharge at the proposed site shall be made available to the agency.
2. Information concerning quality of the water to be recharged and receiving waters shall include chemical, physical, biological, and radiological data. Chemical analyses and data shall include all specific elements, chemicals, and compounds that are or might be detrimental to health, including heavy metals as well as those that might impair the quality of the receiving water.

3. Quality of water data shall include changes that occur due to seasonal variations of the recharge water.

4. No permit shall be issued that will result in the indigenous ground water quality exceeding the chemical levels for raw or untreated drinking water supply sources as specified in the National Drinking Water Standards, including future additions and modifications.

5. A permit shall not be issued if the agency determines that the information supplied indicates any hazard to the public interest.

6. Monitoring wells shall be established to measure water levels in the ground water reservoir receiving artificial recharge. Water levels shall be measured monthly and reported to the agency.

7. Monitoring wells shall be established to determine the ground water quality in the receiving reservoir. Water quality data shall be submitted to the agency bi-monthly.

8. At least two monitoring wells shall be placed in the vicinity of the artificial recharge system. The wells shall be at different depths, with the shallower well screened in the upper part of the aquifer and the deeper well screened in the lower part of the aquifer. The wells shall be located in a regional hydraulic downgradient direction from the recharge facility, but at a distance of no more than ____ feet from the recharge well or pit.

9. Records describing the quantity of water artificially recharged each month shall be submitted to the agency annually.

10. Water artificially recharged to the ground water in any manner by any methods shall meet the requirements of the state water

quality standards in all respects at the time the recharge water intercepts the ground water.

11. Water quality data relative to the artificial recharge facility shall be submitted to the agency annually. Water quality data shall be collected and analyzed by the operator on a schedule established by the agency, but in any case no less than bi-monthly. The records shall include the chemical, physical, biological, and radiological quality of the water being recharged and the chemical, physical, biological, and radiological properties of the ground water in the vicinity of the facility that has been mixed with the recharging water.
12. Deterioration of the chemical, physical, biological, or radiological quality of the receiving ground water will necessitate either the closing of the system or corrective engineering. The degree of deterioration of the ground water reservoir that will be permitted will be established by the agency.
13. The permit application shall be accompanied by a proposed plan or alternative plans of action to be followed in the event the proposed facility causes ground water pollution.
14. The owner and operator of the artificial recharge works shall be liable for any ground water pollution caused by dissolution of any toxic or hazardous material in the soil which are transported to the ground water during the process of artificial recharge, even though there is no knowledge of the toxic or hazardous materials in the soil prior to the recharge.

16. DISPOSAL WELLS

Commentary on the Protection of Ground Water

Many different types of wells, ranging widely in depth, have been used to dispose of waste materials underground. These include oil field formation water return wells, solution mining wells, and industrial and municipal waste injection wells. For many years, wells have been used for the injection of sewage and desalinization plant brine. Wells are also used for reinjection of brine originating at geothermal energy plants. Radioactive wastes, which are extremely toxic and generate heat, are pumped underground either as a liquid or mixed with a cement slurry.

For scores of years, huge quantities of liquid wastes have been injected underground and presently more than a billion gallons a day are pumped into subsurface strata. The vast majority of these wastes consist of oil field brines and, although there have been several reported cases of fresh ground water pollution caused by their injection, the techniques are reliable and well established. Within the past 30 years, there has been an increasing number of other types of wastes injected. The techniques used are similar to the older, more established oil field brine disposal methods. The return of an oil field brine to the original producing zone, however, may differ considerably in hydrodynamics and geochemistry from deep well disposal of certain other wastes.

Within the past ten years, deep well disposal techniques have become more sophisticated and regulations more demanding. The number of industrial disposal wells has also increased significantly in the past few years -- from about ten in 1953 to more than 275 in 1972. Their increase is largely due to the recognition by industry that they represent an attractive and, in most cases, less expensive means of disposing of highly toxic or noxious liquid waste products. In addition, these wastes are believed to be stored in a confined reservoir system that is far removed from topographic and climatic influences and in which vertical migration is insignificant. In many situations, however, these assumptions have proved to be invalid.

Local ground water pollution problems related to waste disposal through wells have been reported in Florida, New York, Oregon, Idaho, Ohio, and elsewhere. Perhaps the most widespread problem is the gravity feed injection of raw sewage into relatively shallow wells that tap porous limestone deposits. Another potential for pollution occurs in areas where abandoned and unplugged wells connect the disposal zone with shallower aquifers. Pressure injection may cause a considerable rise of the potentiometric surface. In Florida, pressure effects spread out more than 25 miles from the disposal well. In southeastern Michigan and adjacent areas in Ontario, several abandoned wells began to flow highly mineralized or polluted water in response to increases in reservoir pressure brought about by deep well disposal.

Well injection of waste materials can modify the ground water flow system and pressure distribution. It can also lead to mixing of waters of perhaps vastly differing chemical and physical properties. Well injection could also degrade fresh ground water supplies; contaminate other resources, such as oil, gas, coal, brines, or other minerals; provide the triggering mechanism for the generation of earthquakes; and could also lead to adverse chemical reactions between the waste water and the ground water or between the waste water and the aquifer framework.

In order to control or prevent pollution of ground water by disposal wells, a considerable volume of information is required. Only after careful and detailed evaluation of the data should a permit be issued. An evaluation should begin by development and understanding of the regional hydrologic framework of the disposal zone and adjacent strata. Information required includes thickness of strata, permeability, areal extent, fractures, and other geologic features. Secondly, the local hydrologic situation should be examined and immediately followed by an evaluation of the effects of waste fluids on the aquifer framework and the contained water. There must be an acceptable compatibility between any waste fluids and those fluids native to the aquifer.

A permit should require suitable well construction and adequate hydrologic testing of the disposal zone during the construction and the testing phase of disposal well installation. Aquifer characteristics and responses to injection, as well as the direction and rate of waste movement, must also be determined. Generally, some restrictions on the operating programs for the wells will be required. Each site should have equipment and programs for emergency procedures in the event of malfunction, including rapid shutoff, standby, and decontamination facilities. Strict guidelines should be established for disposal well abandonment and plugging.

A waste monitoring system must be carefully maintained and managed. In most cases, disposal wellhead pressure should be continuously recorded, with alarm systems and observation wells installed in the injection zone or in adjacent aquifers.

A great deal of technical knowledge is required to adequately examine the data in an application for a permit and to determine the feasibility of well disposal. For these reasons, among many others, it is more feasible to issue a permit based on the consensus of several state agencies such as the state geologist, state health officer, the director of the state Environmental Protection Agency, Department of Natural Resources, Water Commission and other appropriate agency. Each permit must be handled on a case-by-case basis.

Requirements for the installation of a disposal well are contained in federal regulations adopted under the Safe Drinking Water Act (P.L. 93-523). The regulations establish minimum requirements for state programs in those states listed by the Administrator of the U. S. Environmental Protection Agency as those for which an underground injection control program is necessary to assure that underground injection will not endanger drinking water sources. Any state considering adoption or modification of regulations governing this subject should consult the current regulations under 40 CFR Part 146.

17. WATER SUPPLY WELLS

Regulations for the Protection of Ground Water

Water well regulations have a dual purpose: they are intended to prevent contamination of the water taken from the well for human consumption, and at the same time to prevent pollution of the water resource upon which the well depends. If a well is adequately constructed and maintained to accomplish the first purpose, which is the emphasis of most state regulations, the second will also be likely to be served. It is when a well is abandoned that the second purpose is likely to be neglected, since the effect of improperly abandoned wells on the quality of water in the aquifer usually will not be perceived for many years.

Improper construction of a well may consist of improper seals that permit inflow of highly mineralized or polluted water, or it may consist of casing that is unsufficient in length, corroded, or broken, thus providing a pathway for entrance of pollutants. In other cases, the annulus or open space between the casing and the outer wall of the drilled hole may not be properly grouted or there may be no grout at all. Wells have also been affected by backfilling the annular space with polluted fill. A great number of water supply wells are constructed in low areas that are subject to flooding; highly polluted flood waters may leak into the well because of inadequate protection. Any time a well is constructed or serviced, it should be disinfected. Improper technique or lack of disinfection has caused severe problems.

Most states have at least some well construction standards, although authority may be scattered in several agencies. Well construction codes range from none to highly sophisticated concepts. Model standards need to describe, in considerable detail, a wide variety of geohydrologic situations and adequately outline the best technology for each case. A report will soon be published by the U. S. EPA that describes, in great detail, model water well construction standards.* The technical standards of the report describe:

1. Test holes and samples
2. Well construction
3. Well casing selection and installation
4. Well grouting

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*Recommended Water Well Construction Standards, National Water Well Association - U. S. Environmental Protection Agency, 261 pages.

5. Well screens and perforations
6. Well filter construction (artificial)
7. Well plumbness and alignment
8. Well development
9. Well testing for performance
10. Well disinfection
11. Water samples and analyses
12. Permanent and test hole abandonment and temporary capping

It is strongly recommended that state agencies desiring to develop new or to modify existing water well standards consult the above cited report when it becomes available.

In addition to specific well construction standards, a number of states have required drillers to either become registered or to obtain a well drilling license and file a surety or cash bond in order to drill water wells. The license is issued on the basis of education, drilling experience, and examination.

The licensee is required to submit to the control agency a well drilling report and log of each well constructed by him within the State. A driller's license may be revoked for noncompliance or for the submission of false or erroneous data.

Geologic and hydrologic conditions are so varied throughout the United States, or for that matter within a single state, that it would be impractical to present here a single set of well construction standards adequately describing every condition that may be encountered. For this reason only, a few generally broad model regulations are provided. The reader is also referred to regulations on the abandonment of wells found elsewhere in this report.

REGULATIONS

1. Every person, prior to construction or modification of a water well, shall obtain a permit from the agency.
2. Every water well shall be constructed in a manner to avoid waste and ground water pollution.
3. Every water well shall be maintained in a condition and manner so as to conserve and protect ground water quality.
4. Well casing shall be installed in every water well and shall extend a minimum of ____ feet above the land surface and to a minimum depth of ____ feet below land surface.
5. Well casing shall be sealed to prevent downward movement of surface water in the annular space around the casing and to prevent upward movement of artesian waters that could result in waste or pollution.
6. Every well shall be disinfected upon completion of construction, maintenance, repairs, pump installation, and testing, as prescribed by the agency.
7. Every well that flows under natural pressure shall be equipped with a valve that will completely shut off the flow, or the well shall be plugged by the methods required for plugging permanently abandoned wells as established by the agency.

8. On completion, every water well shall be tested for yield and drawdown by the methods prescribed by the agency. Yield and drawdown data shall be submitted to the agency within ____ days of completion of the test.

9. Every well shall be equipped with a usable access port installed and maintained to prevent entrance of foreign materials and to permit ready access for water level measurements.

18. EXPLORATION HOLES AND ABANDONED WELLS

Regulations for the Protection of Ground Water

The leakage of contaiminated or highly mineralized water through long abandoned wells and unplugged exploration holes has led to insidious ground water pollution problems. The greatest share of these problems was not discovered for years, until wide areas were adversely affected. In Michigan, for example, thousands of holes were drilled for exploration of oil, gas, and coal resources before the turn of the century. Over the past 80 - 100 years, leakage of billions of gallons of highly mineralized solutions through these open abandoned holes has created problems that encompass vast areas. Unquestionably, many other areas throughout the country have been affected by similar practices. It should be pointed out, however, that for the past several years oil and gas tests and wells must be adequately plugged in order to meet state regulations. Leakage of acid mine drainage through ancient oil and gas wells and other open holes has allowed extensive ground water pollution in the coal fields of Pennsylvania and elsewhere in Appalachia - a region where water resources are already greatly stressed by the discharge of acid waters from the mines.

Since World War II, deep well disposal systems have increased greatly in popularity and utilization, particularly in industrial regions. Injecting waste solutions into the underground, however, may tend to repressure the reservoirs causing the water pressure surface to rise several tens of feet. Particularly in Ontario and southeastern Michigan, the increased pressure has caused brine to flow from long abandoned unplugged oil and gas holes and wells, the locations of many of which were previously unrecorded and unknown.

In many cases, it is neither technically nor economically feasible to plug all ancient abandoned wells and exploration holes. Steps must be taken, however, to insure that wells and exploration holes drilled or abandoned in the future will be properly plugged in order to protect ground water resources and public health as well.

Several techniques could be used to develop some administrative controls over the drilling of exploration holes. The simplest and most straightforward technique might consist of special drilling licenses and permits to prospect. A special driller's license, necessary for all types of drilling, could be issued by an agency of state government. The special license concept is attractive because it is not feasible to issue permits for all exploration holes, as for example thousands of seismic shot holes. Noncompliance with the regulations could be handled with a fine or revocation of the driller's special license. Permits to prospect could also be required. A permit could be required to drill a single exploration hole or a block of holes as in the case of seismic work. Special licensing of drillers for this type of drilling would give the states some control over both drilling and plugging of wells and exploration holes.

Unsealed abandoned wells and exploration holes constitute a hazard to public health, safety, and welfare, and to the preservation of the ground water resource. The sealing of such wells presents a number of problems, the character of which depends upon the construction of the well, the geological formations encountered, and the hydrologic conditions.

The basic concept of proper sealing of abandoned wells is the restoration, insofar as feasible, of the controlling hydrologic and geologic conditions that existed before the well was drilled and constructed.

Any permanently abandoned well should be completely filled in such a manner that vertical movement of water within the well bore, including vertical movement of water within the annular space surrounding the well casing, is effectively and permanently prohibited and the water is permanently confined to the specific strata in which it was originally encountered.

A well should always be checked before it is sealed in order to insure freedom from obstruction that may interfere with effective sealing operations. Removal of casing from some wells may be necessary to assure placement of an effective seal. If casings opposite water bearing zones cannot be readily removed, they should be split with a casing ripper to assure the proper sealing of these water bearing zones. At least the upper portion of the casing should be removed to prevent surface water from entering the water bearing strata by flowing down the casing. This operation is not necessary if the annular space around the outside of the casing was cemented when the well was completed.

Grout of any type, when used as a sealing material below the water level in the well, should be placed from the bottom up by methods that will avoid segregation or dilution of material.

Every effort should be made to disinfect wells prior to abandonment. Also, all materials, such as water, sand, and gravel to be used in the abandonment process should be disinfected.

(Detailed well abandonment and plugging techniques are described in EPA-NWWA Recommended Water Well Construction Standards)

REGULATIONS

1. Every person intending to drill, bore, or in any manner excavate an opening in the earth for the purpose of evaluation of under-

ground resources, including but not limited to metallic and nonmetallic deposits, oil and gas, coal, water, and brine shall apply for a permit from the agency. The permit application shall describe the location of the hole or block of holes, their purpose, estimated depth, type and amount of casing, if any, procedures proposed for plugging, hole diameter, water level, type, permeability, thickness and quality of water of any aquifers that will or might be penetrated, and emergency containment procedures to be initiated in case of abnormal bore hole fluid or gas pressures.

2. The term of the permit shall be ____ months, subject to renewal.
3. The permit application shall be accompanied by a performance bond or other surety, the amount of which is based upon the number of exploration holes to be constructed, their proposed depth, and geologic and hydrologic conditions.
4. The bond, if forfeited, will be used to restore the site, or in the case of pollution, restore the ground water to its original state. In the event of forfeiture of bond, the operator will not be eligible for future permits.
5. Every person who drills a hole, boring, or excavation to be used for the exploration for underground resources, including but not limited to metallic and nonmetallic deposits, oil and gas, coal, water, brines, and engineering properties, must possess a valid special drillers license issued by the agency.
6. The special drillers license may be revoked by the agency for failure to comply with a regulation contained in this section.
7. The owner of an exploratory well, boring, or excavation shall not allow leakage that causes ground water pollution.

8. A boring, well, or excavation used for the exploration of underground resources, including but not limited to metallic and nonmetallic deposits, oil and gas, water, and brines, shall be adequately sealed within ____ months of its construction. The method of sealing shall be based on the geologic formation penetrated, but in such a manner as to prevent the exploratory hole from acting as a channel for the migration of mineralized waters into potable zones, or the escape of subterranean gases. A proposal for sealing methods shall be submitted to the agency for approval prior to plugging.

9. The emplacement of grout or sealing material shall adequately shut off all permeable formations.

10. An abandoned well shall be filled and sealed in accordance with the geological formations penetrated, in such a manner as to prevent it from acting as a channel for pollution, or the escape of subterranean gases. A proposal describing the method of sealing shall be submitted to the agency for approval prior to plugging.

11. Abandonment of wells containing subterranean gases requires special precautions and a casing in such a well shall be sealed with neat cement grout or concrete grout.

19. OIL AND GAS - ADDITIONAL RECOVERY

Regulations for the Protection of Ground Water

There are two primary risks for aquifers related to the development of oil and gas, and particularly to the additional recovery of oil and gas. The most common of these is poor well design or construction, resulting in pollution of the fresh water aquifer by a brine solution due to casing or grout failure. The second of these is the possibility of a change in the natural pressure system causing a leak or "bleed-through" along a fault or fracture plane forcing brine into the fresh water aquifer.

These risks can be minimized, if not entirely eliminated by: careful planning, including good well design, thorough analysis of reservoir conditions, mapping of all potential fresh water aquifers and aquicludes, and identification of potential fault planes, etc.; good construction of wells and thorough grouting and sealing of the aquifers present; monitoring of the fresh water aquifers throughout the period of the operation to be certain that they are not being polluted; and a prepared plan of action in the event pollution does occur.

These regulations should be supplemented or modified as necessary to conform with current federal regulations in 40 CFR 146 adopted pursuant to the Safe Drinking Water Act (Public Law 93-523) in any state which has been listed by the Administrator of the U. S. Environmental Protection Agency as one for which an underground injection control program is necessary to assure that underground injection will not endanger drinking water sources.

REGULATIONS

1. Every person undertaking an additional recovery project for the production of oil or gas shall obtain a permit from the responsible State agency.
2. The permit application shall include a detailed description of all geologic and hydrologic conditions present, including consolidated and unconsolidated deposits, and streams and other surface features. The application shall map and describe the oil and gas reservoir, and all known and potential fresh water aquifers within one mile of the proposed project. This map shall

include the locations of all unsealed abandoned wells within 2,000 feet. Known and suspected fractures of any nature shall be indicated.

3. No pollution of fresh water aquifers by the secondary recovery operation is permitted.
4. The permit application shall include a complete description of casing and grouting procedures that will be observed, the working pressures to be used, and shall certify that no pollution of fresh water aquifers will occur.
5. The permit application shall include emergency procedures that will be followed in the event pollution does occur. These shall include cessation of operation until the necessary corrections are completed.
6. Each water flood operator shall notify every owner of a fresh water well within one mile of the water flood project with regard to the nature of the project. The fresh water well owners shall be given, in writing, the address and telephone number of the responsible State agency to which they may report if problems develop in their water supply wells.
7. A monitoring program shall be conducted throughout the life of the project to verify that pollution of the fresh water aquifers is not occurring.

A minimum of four monitoring wells, one in each quadrant of the project site, shall be established and monitored for each known or potential fresh water aquifer. The location of each of these wells shall be included in the permit application. Multiple aquifers may be monitored by a single observation well. If an increase in chloride content occurs, the specific zone affected must then be determined and corrective action taken.

These wells shall be sampled weekly for the first two months of the project and monthly thereafter. Samples shall be analyzed for chloride content, and such other constituents as may be significant in establishing pollution.

Additional monitoring wells or sampling frequency may be established by the agency if determined to be necessary for monitoring the project.

8. Upon completion or abandonment of the project all holes shall be grouted shut to their full depth. For minimum grout specifications see EPA-NWAA Recommended Well Construction Standards.
9. The water flood operator shall provide, with the permit application, a performance bond in the amount of at least $100,000.00, or such additional bond as required by the agency as a consequence of the magnitude of the project.
10. Any violation of the permit conditions or these regulations, without full observance of the emergency procedures as submitted with the permit application, shall result in forfeiture of bond.
11. The bond, if forfeited, will be used to restore the site. In the event of forfeiture of bond, the operator will not be eligible for future permits.

20. MINING

Commentary on Protection of Ground Water

A wide variety of mining techniques are utilized in the United States. Existing methods, as well as newly emerging techniques, have caused water pollution problems, particularly of surface water. In many situations, pollution problems are attributed to on-site mineral preparation plants rather than to the mining process itself.

Mining techniques include underground methods, surface mining, mining by solution, leaching, and in-situ combustion. Although techniques differ widely from one resource to another, underground mining methods consist of removing ore through some type of opening such as shafts, drifts, or stopes. Surface mining includes strip and open pit, auger, dredging, and hydraulic. During solution mining, hot fluids are injected into the deposit, dissolving it and then the pregnant liquid is withdrawn through wells. Leaching methods consist of the dissolution of the ore by solvents, which are distributed over dumps, heaps, in vats, or undisturbed ore bodies, where it infiltrates. The enriched leachate is then collected and processed. Although used only slightly in the past, in-situ combustion is being carefully examined as a means for processing oil shale. In this process the oil shales will be fractured and then ignited. The heat will decrease the viscosity of the hydrocarbons permitting released liquids and gases to migrate to collection points, such as wells.

The major water pollution problems in mining regions are due to leakage of water through the mines, slime ponds, spoil piles, or mill wastes. The leachate, which consists of highly mineralized, commonly acidic fluids, may be generated long after the mining operation has ceased.

Mining activities almost always disrupt both the regional and local ground water flow systems. Since many mines extend below the water table, they must be dewatered. In addition to a substantial decline of the water level, this may lead to induced infiltration of stream flow, interaquifer leakage, or flow through open holes. Water pumped directly from the mine may also contain large concentrations of dissolved solids. Acid solutions formed by the infiltration of water through mines and waste and milling piles may lead to the accumulation of significant concentrations of heavy metals. During leaching and solution mining, the reacting fluids may pollute adjacent ground water resources. In-situ combustion has caused great increases in the dissolved mineral content of adjacent water. Furthermore, evaporation of the mine waters leads to increased mineralization. A relatively minor problem is caused by wind removing fine particles from tailings, and mill wastes that settle out downwind. Although not a part of the mining activity, a future potential source of ground water pollution looms on the horizon as administrators look to abandoned mines as a depository for waste products.

Several manuscripts are available that describe methods for controlling ground water pollution from mining activities. Four excellent reports of this type include:

1. Processes, procedures and methods to control pollution from mining activities, 1973, U. S. EPA Publication, EPA-430/9-73-011.
2. Rationale and methodology for monitoring ground water polluted by mining activities, 1974, U. S. EPA Publication, EPA-600/4-74-003.
3. Mine drainage manual, 1966, Pennsylvania Department of Health.
4. Environmental protection in surface mining of coal, 1974, U. S. EPA Publication, EPA 670/2-74-093.

Additional guidelines will need to be developed for new mining techniques and areas, such as those in the Great Lignite Fields and the vast oil shale deposits.

Ground water pollution problems caused by mining activities can be controlled, at least to some extent, by:

1. Existing reclamation laws
2. Surface water quality standards
3. Air pollution standards
4. Holding pond and lagoon regulations
5. Wastepile and stockpile regulations
6. Abandoned well and exploration hole regulations
7. Detailed permit procedures.

Before a permit is issued to develop a new mining activity, detailed planning and hydrologic studies should be conducted, including determination of the hydrologic framework, flow-patterns, and ground water quality. In the past, the ground water phase of the hydrologic cycle was largely ignored in planning and premining surveys, as well as subsequently in reclamation. Permits should also require examination of potential effects on mining, not only during the premining phase but also during the operation and following abandonment. The hydrologic data should be used in the design of the mine and the operation should be based, at least in part, on it.

Ground water quality in mining areas can be monitored by means of wells, springs, seeps, and streams. Water levels should be measured. Monitoring of both quality and water levels should be continued throughout the mining and postmining phases.

21. GROUND WATER DEVELOPMENT

Commentary on Protection of Ground Water

The primary problems resulting in ground water pollution due to development, or production, of aquifers are caused by (a) poor well construction or condition, resulting in pollution from the surface or intermining between aquifers; (b) overdraft, causing local reductions in head and "coning" or intrusion of brines or salt water; and (c) pressure reductions in one artesian aquifer and infiltration from another of inferior quality.

The first of these problems is related to well standards, and is treated in that section of these regulations.

The latter two problems are the direct consequences of production and can only be prevented by planning and management. In some instances it may be permissible to accept a certain level of salt water intrusion, in order to effectively utilize the available ground water on an economical basis. In many other instances this is completely unacceptable, and either reduced draft must be accepted or a barrier must be established to prevent the salt pollution.

The significant factors here are comprehensive evaluation, planning, and effective ground water management. There are no specific regulations that can be enforced that will lead to the type of management that is required. Rather, each State wherein this problem exists, or potentially exists, must establish a comprehensive management plan, with enabling legislation to permit the State to limit withdrawals, and establish recharge programs or other management tools in critical areas, when required.

These requirements are important in coastal areas, but also throughout large areas of the interior, where shallow aquifers are polluted by contiguous mineralized deposits.

CHAPTER V

MANPOWER REQUIREMENTS AND IMPLEMENTATION OF A STATE GROUND WATER PROTECTION PROGRAM

A. MANPOWER REQUIREMENTS FOR A MODEL STATE GROUND WATER PROTECTION PROGRAM

The effective utilization of ground water is attainable only by the commitment of adequate manpower to prevent, or at least control, its pollution. The regulations, guidelines, and commentary presented in Chapter IV create manpower demands in five major categories. These are: a) Planning and Coordination b) Permitting and Licensing c) Monitoring and Data Collection d) Enforcement and e) Research.

Due to the complexity of the occurrence of ground water, in addition to the complexity of its physical and chemical nature, its management can only be attained by persons with specialized knowledge of both its physical properties and its occurrence. Expertise is required not only with respect to the various technical disciplines that are involved, but also with regard to specific locations. To illustrate, a person highly qualified to deal with problems of ground water quality and quantity in Florida may require substantial new experience before solving equivalent problems in Montana. Effective utilization can only be attained by persons with expertise in the bacteriological and chemical nature of water.

Considerable inter-disciplinary knowledge is thus required, involving on the one hand geology, hydrology, and geochemistry, and on the other hand civil and sanitary engineering, with health requirements always being of a high level of importance.

In general it can be stated that the geological sciences are primarily involved in the occurrence, movement, and management of ground water resources; the engineering sciences are primarily involved in the utilization of ground water resources; the chemical sciences are involved in the evaluation of water quality; and health sciences have an overriding involvement when there is a public health issue. Additional technological knowledge is required from many other disciplines, such as: agricultural engineering, particularly with regard to problems related to fertilizers, pesticides, and feedlot operations; petroleum engineering with regard to problems related to gas and oil production; land planning with regard to the protection of critical ground water recharge areas; and many others.

PERSONNEL REQUIREMENTS

Table I shows the 21 major activities requiring regulation in order to protect ground water. Vertically, at the left of the chart, are plotted the five major work categories, or Manpower Functions, that are required for each proposed ground water regulatory activity and the level of expertise that is required.

The manpower requirements identified in Table I are related solely to the ground water protection program, and are in addition to any other pollution control effort that may be in effect regarding the proposed

21 Regulated Activities. For example, many health departments already effectively regulate septic tank design. Table I only shows the input required for protecting ground water, not the many other aspects of septic tank regulation. Not included in the table are requirements for auxiliary services, such as laboratory services, legal services, and non-professional administrative personnel. It should also be noted that the manpower identified herein are not adequate to evaluate or correct old, pre-existing problems, such as those related to abandoned wells, abandoned mines, etc.; such corrections will require special programs.

The restriction of Table I to the consideration of ground water should not be construed as a failure to recognize the relationship of ground water to surface water nor of its proper perspective regarding the hydrologic cycle nor the environment as a whole. These points have been stressed throughout the earlier chapters of this document. The objective of this presentation is to identify the level of effort necessary to raise the present low level of ground water awareness to a position commensurate with its actual importance in the national economy.

The manpower requirements shown are based upon the collective experience of the task force committee that prepared this manual. Critical areas have been verified by comparison with ongoing programs in selected parts of the country. They are felt to be sufficiently reliable to provide a basis for starting or evaluating operations in any state. Each state must then make specific adjustments for its own conditions.

A state with a high incidence of any particular regulated activity should acquire greater efficiency than indicated in the table. On the other hand, a state investigating its first disposal well will certainly require more time than is indicated.

An important point to note here, however, is that throughout the proposed regulations the burden of preventing pollution, and project justification, is placed upon the potential pollutor. The state controls activities by permits and licenses; accumulates knowledge by monitoring, data collection, and research; protects the public by enforcement; coordinates the activities of ground water with those of other areas of public interest, and, through planning, attempts to be prepared for the future activities that will be required.

It is intended that strict enforcement will be effected by moderately severe penalties and "spot" checking, thus avoiding the extreme costs of continuous, close inspection.

AREAS OF TECHNICAL SPECIALIZATION

Table II, constructed on the same basis as Table I, indicates the specialized expertise that is required in each portion of the Regulated Activity/Manpower Function matrix. Capital letters indicate that input from the specific specialty referred to is mandatory. Lower case indicates that the actual quantity of this input is not considered, but is rather left to individual discretion. This is necessary since the importance of some disciplines, such as health, is often not a function of time. In some instances, input from several disciplines is required with the bulk of the work done by still another.

The intent of Table II is to identify mandatory areas of specialization for an adequate program, and to identify auxiliary disciplines that will prove not only compatible but beneficial.

A description of the general responsibilities of each of the Manpower Functions follows. The only significant difference, considered to be between professional and senior professional personnel, are advanced academic degrees and experience. Most governmental agencies have the mechanics for this differentiation already in effect.

Grouping by function does not indicate an organizational arrangement. Whether all responsibilities listed under one of the following "functions" are placed in one section or agency will depend upon a state's agency structure.

Planning and Coordination Function

Responsibilities for planning and coordination include but are not limited to:

1. Identify critical ground water areas.
2. Prepare and maintain ground water development and management plans.
3. Encourage technology to prevent ground water pollution and rehabilitate polluted aquifers.

4. Consult with persons concerning ground water pollution sources and prevention techniques.
5. Make recommendations concerning policy and legislation.
6. Establish training and educational programs.
7. Provide for advisory committees.
8. Make recommendations to other agencies for adoption of regulations affecting ground water.
9. Disseminate information.
10. Anticipate ground water problems.
11. Coordinate activities and personnel with other agencies.
12. Investigate and evaluate sites to be used for future ground water development.

Positions require a wide range of administrative ability coupled with both practical and theoretical experience. It is essential that these positions be filled by individuals with backgrounds in science and engineering as well as the social sciences.

The professional staff is visualized as consisting of several individuals with specialized fields of expertise but with the ability to grasp the significance and importance of interrelated specialties. Duties and fields of expertise of several of the professional staff would overlap and complement each other. A prime duty of this staff is coordination and cooperation with other state, federal, and local agencies.

Permit and License Function

Permit and license personnel examine permit applications and supplementary data provided by the applicant and the agency staff in order to approve or disapprove sites or plans for activities 1-3, 7, and 11-20 in Table I. Responsibilities also include, in consultation with other personnel in the agency, the development of written examinations required for the issuance of licenses for persons constructing, drilling, or plugging wells, or persons involved in the drilling of exploration holes.

These personnel examine permit applications and supplementary data, in conjunction with field site investigations, in order to recommend approval or disapproval of a permit application for activities 1-3, 7, and 11-20 in Table I.

The professional background of personnel performing this function is designated in Table II. However, due to the complexity of the information submitted by applicants, each state should take steps to insure that the person finally approving any application has adequate experience to make the judgments involved.

Monitoring and Data Collection Function

Responsibilities include the development of data acquisition, storage, and retrieval systems; and monitoring of water withdrawal and activities that may lead to ground water pollution. Also included are data collection and monitoring of potential sites that may later be required for waste disposal or ground water use activities. Reports will be prepared at regular intervals and distributed throughout the agency, to other appropriate state agencies and commissions, and be made available to the general public. If a ground water quality problem appears imminent as determined from monitoring activities or by other means, a report will be submitted immediately to Enforcement personnel for further investigation. It is envisioned that all of the data collected will be stored in a computer bank for quick retrieval and evaluation. Furthermore, this function requires digital computer techniques for hydrologic and water quality modeling.

Individual responsibilities include site investigations for the purposes of locating monitoring wells and data collection points, installing monitoring systems and providing technical aid to permit applicants so that other than agency monitoring sites can be located and operated in such a manner as to provide maximum information. Agency monitoring sites and equipment will be operated and maintained by these personnel.

In addition to general administrative duties and general clerical work, the staff will be responsible for key punching data for computer storage and retrieval. Computer time must be provided on a pre-defined time basis.

Enforcement Function

The major responsibilities under this heading are inspection and data collection in order to require compliance with the terms established in permitting procedures. Some of the senior professionals will be required to possess legal or paralegal training in order to initiate compliance orders, injunctions, and actions. Coincidental duties include technical evaluation of data submitted to the agency by the permittee as well as those collected by the agency. The major responsibility is to ensure compliance with terms of the permit so that ground water pollution or ground water withdrawals in excess of allowable amounts do not occur. In the event the terms of a permit have been exceeded, it is the responsibility of the senior professional staff to initiate action to remedy the offense through consultation, advice, permit modification, or legal action.

This professional staff would also conduct field inspections to insure that violations do not occur and that inefficiencies are corrected. Field investigations will include onsite examination and sample collection. A knowledge of the techniques of sample collection, storage, and transportation relative to the rules of evidence are mandatory.

Legal expertise in hydrological problems should be developed on a full-time, permanent basis, and work coordinated, in most states, with the office of the Attorney General.

Research Function

The major responsibilities of the research staff are to investigate means for reducing water quality problems, including development of improved techniques for monitoring, and education. Responsibilities, in addition to conducting studies and performing research, include data collection, information dissemination, consultation, making of recommendations concerning policy and legislation, establishment of training and educational programs, acting on advisory committees, and soliciting research. Research activities, including both pure and applied studies, should be largely dictated by the activities and needs within the particular states. The senior staff will be responsible for evaluating and establishing priorities of research needs, conducting research, and directing activities of the professional staff. The staff will also have the responsibility of developing and conducting educational short courses, seminars, and lectures.

Duties include laboratory and field investigation research activities. The professional staff will be largely responsible for the actual research, which will be directed by the senior staff. The professional staff will also be involved in the preparation of educational materials and reports that will be used in short courses, seminars, and lectures. In view of the different fields of expertise among the research professionals, close cooperation and communication both within the section and the agency is a necessity.

Duties will include general clerical work, but laboratory and field technicians, and draftsmen, are essential.

A Ground Water Training Program

Table I attempts to identify the manpower required to address the various activities that pollute ground water. These manpower estimates are generally geared to one million population increments and thus allow an extrapolation of the estimates to the needs for a state program based on its population or, in fact, the needs of the entire country.

Using a figure of 220 million for population of the United States, an extrapolation of Table I shows a need of approximately 5,250 man years of effort to adequately permit, license, monitor, collect data and enforce whatever regulations a state might develop for the 21 activities that affect ground water. Recognizing that certain activities are not universal problems, such as highway salting in southern climates and landfills in arid climates, and that estimates in this manual may reflect a conservative bias toward protection of ground water, an estimate of 5,000 man years would appear to provide a workable figure to use in attempting to arrive at some cost estimates for a training program.

If, in fact, 5,000 man years of effort are needed for a nationwide program, exclusive of the planning and research functions, it should be obvious that considerably more than 5,000 individuals with some training in ground water will be needed. This is so because, as the next chapter will indicate, it is expected that the ground water protection program will be divided among a number of state agencies which also have a wide variety of non-ground water activities. It seems reasonable, therefore, to assume that the average state employee assigned to some ground water protection activity would spend only half his time in this work category. Thus, to achieve 5,000 man years of input per year, a total of 10,000 individuals must become involved in the national program. This would be an average involvement of 200 persons per state. When one considers that to some extent, county health officials will comprise part of the manpower for a number of ground water functions, a number of 200 persons per average state does not seem unobtainable from a training standpoint.

Working from this premise, a basic training program could be developed, the purpose of which would be to give the 10,000 persons in the above estimate a familiarity with the nature and occurrence of ground water, and the problems in protecting its quality, that they do not now possess. It is not proposed as a substitute for education of specialists in the various fields related to ground water protection. It assumes that there is a considerable lack of awareness of ground water, its value, and the effects upon it from various common activities, among those persons now working in public agencies whose programs relate to health, natural resources, and the environment.

The training program envisioned would attempt to assure that four "key men" from each state, regardless of size, would have sufficient training to enable them to conduct training programs in their states. These 200 professionals would be trained by means of an intensive two week course drawing upon the knowledge of the nation's leading ground water experts. In order to establish the necessary close rapport of a workshop training program, a limit of 50 students should be enrolled in each two week training program -- thus four such programs would be needed. These could be held in four regions of the country and keyed to the problems peculiar to the region.

Those chosen for the regional two week training programs would be expected to have college degrees in scientific disciplines broadly related to ground water geology or hydrology. Such related disciplines as Agricultural Engineering, Civil or Sanitary Engineering, Petroleum Engineering, or Soil Science (see Table II) would supply individuals with the basic training to grasp the specialized concepts of ground water protection technology which would be taught. These people would most likely be individuals in existing programs of Health, Environmental Protection, or Natural Resource Conservation who have shown particular promise as leaders, planners, and perhaps educators.

It is estimated that a curriculum development project for such an intensive course would cost approximately $30,000. Included in this cost would be the development of variable one week course curricula which those trained in the regional courses could in turn offer to appropriate personnel in their states. Instruction on how to present their own educational programs would be included in the regional two week program. Each two week program for 50 students is estimated to cost $85,625 as shown in Budget Schedule I for a total cost of $30,000 + 4 x $85,625 = $372,500 for these "key man" programs.

It is anticipated that the graduates of these regional courses will establish education programs in their own states for an average, per state, of 200 individuals with some responsibility for protecting ground water resources. Budget Schedule II shows a projected budget for a sample state training program for 200 public employees to be $87,700 with the bulk of the costs covering travel, room, board and materials.

Nationally, this training effort by the states could be underwritten at a cost of 50 x $87,700, or $4,385,000. Adding the cost of regional "key man" courses, the total would be about $4.75 million.

It should again be emphasized that the student-state employees included in these training courses are not neophytes in state environmental protection programs. They would each be expected to have the background education identified in Table II and be actively engaged in some related facet of the work through their state Environmental Protection Agency, or Department of Health, Natural Resources, Geological Survey, etc.

As an additional aid in establishing a viable state ground water protection program, states might consider establishing voluntary short course programs for individuals not directly involved with ground water cases but who are peripheral to it. Legislators, municipal officials, supervisors, attorneys, and others who become involved in decisions that affect ground water could be invited to training courses designed specifically for non-ground water personnel.

BUDGET SCHEDULE I

REGIONAL "KEY MAN" TWO WEEK TRAINING COURSES ON GROUND WATER

Personnel

Principal school administrator - 1 month	$ 2,500
Junior school administrator - 2 months	3,000
Secretary - 2 months	1,600
Permanent Faculty (5 man task force) 50 man days @ $250/day	12,500
Guest expert lectures (5 people, 2 days each @ $250/day)	2,500

Travel

50 students air fare and ground transportation @ $300/each	15,000
50 students per diem 14 days each @ $44/day	30,800
5 guest experts air fare and ground transportation @ $300/each	1,500
5 guest experts per diem 2 days each @ $44/day	440

Materials

Books, manuals and reference books $200/student x 50	10,000
Audio-visual equipment rental	1,000
General office supplies for workshop planning	300

Support Cost

Telephone	600
Postage	400
Meeting facility	1,000
Direct Costs	$83,140
Indirect costs (35% of inhouse personnel-$7,100)	2,485
PER REGION	$85,625

Four regions: 4 x $85,625 = $342,500
Plus curriculum development: 30,000

Total (all regions) $372,500

BUDGET SCHEDULE II

SAMPLE STATE TRAINING PROGRAM ON GROUND WATER

Average of approximately 200 people per state

200 students @ $100 travel	$20,000
Subsistance @ $40/day for 5 days	40,000
Facility free at state university	
Training materials $100/student	20,000
Faculty 4 state experts who attended regional 2 week program; travel and subsistance @ $300/each	1,200
Guest lectures - 5 @ $250/day - 2 days	2,500
Guest lecturer travel plus per diem 5 x $400/each	2,000
Audio-visual	2,000
PER STATE	$87,700

Total for all states: 50 x $87,700 = $4,385,000.

B. IMPLEMENTATION OF PROGRAM

The requirements for implementation of the regulations and statutory provisions proposed herein will vary widely from state to state. Enabling legislation, such as is proposed, is already in effect in some states, as are many of the proposed regulations. However, even states with strong current programs may be benefited by evaluation of their existing structure and operation in view of the recommendations in this presentation.

The proposed statutory provisions are written in such a manner that a state with no existing program could adopt them in their entirety. On the other hand, it is anticipated that most often the proposed operations will be integrated into the existing state administrative structure without the formation of a new "super agency" directed specifically toward ground water. In either event it is imperative that ground water be given well defined, specific stature in on-going programs and that its protection and management be given priority commensurate with its importance as a resource.

Perhaps the best way to provide this emphasis, in many states, is by accentuating the planning and coordination function. This will be especially important in instances where the other functions of permitting, monitoring, and enforcement are diffused through several agencies. By concentrating the planning and coordination effort, and by giving it adequate administrative stature, it can assure that the other manpower functions (Table I) are properly conducted even though diffused.

Ideally, at least superficially, it appears that all manpower functions related to ground water should be concentrated in a single state agency. While this has obvious administrative advantages, it would likely be a technological blunder in many states. The regulations proposed herein recommend that permit or license procedures be instigated, or continued, in 15 of the 21 proposed Regulated Activities (Table I). Some of these are already permitted or licensed activities in many states, although it is doubtful that any state currently operates all of the recommended programs. While the importance of ground water historically has been neglected, and ground water should now be given a top priority in regulatory activity, it cannot be considered an overriding concern in every instance. All technological, economic, and social factors should be considered in the administration of the regulated activities being considered. This manual stresses the priority that should be given ground water, and its importance as a resource. It is imperative that it be given either special agency stature or strong technological, economic, and social consideration within existing agencies.

A very basic point that deserves special emphasis here is that it is difficult to administer the activities of permitting, monitoring, and enforcement in the same agency with research. Probably the primary reason for this administrative incompatibility is psychological. Nevertheless, in practice either the research function or the other functions tend to compete and the end result is over-balance in one direction or the other, or apathy. It is, therefore, recommended that research be implemented in a separate state agency. Often this will be best performed through state universities, state departments of natural resources, and combined state/federal programs, but in any event specific and adequate funding should be directed to this activity.

In any state where there is no single agency responsibility for ground water management, utilization, and protection, the activities included under the Planning and Coordination function (Table I) become of extraordinary importance. Otherwise there will be permits issued or denied without reasonable basis, data collected without specific objectives, planning without implementation, and so on.

Where manpower functions indicated in Table I are quite thoroughly diffused throughout the governmental structure it may be necessary for the legislature to give some special legislative "muscle" to the planning and coordination function in order to attain the objectives of the ground water program.

Illustration of Ground Water Activities in a State Organization, Using the Personnel Table

The following illustration shows how ground water functions of a typical state organization may appear on the table of Regulated Activities and Manpower Functions. Tables III, IV, and V show a typical organizational structure of the three state agencies usually charged with the responsibility for water related programs -- an Environmental Protection Agency, a Department of Health, and a Department of Natural Resources. These tables are not intended as models, but simply as illustrations of fairly common types of state organizations.

Table VI, which is a modification of Table I, shows, by texture, the portions of the Regulated Activities vs. Manpower Function matrix that are actually dealt with by the existing agency structure. Those activities performed by the EPA are a light dot pattern (░), those of the Department of Health are a blotch pattern (▒), and those of Natural Resources are a dark dot pattern (▓).

The specific department, unit, section, or division doing the work is identified by a matrix designation at the appropriate place in the responsible agency organizational chart. Thus the ground water protection responsibility for the permitting of a sanitary landfill, matrix designation B-1, is found under the Water Permits Section of the chart in Table III; similarly, the data collection for water supply wells, C-18 on the chart, is found in the Department of Natural Resources under Division of Geological Survey in Table V; etc.

A person familiar with the details of actual agency authority and operation in a state might fill in additional squares. For instance, ground water aspects of animal feedlots, sludge disposal, holding ponds and lagoons, and drainage wells and sumps might in fact be regulated under general provisions of the state's water pollution control law, at least to some degree. In the example, disposal wells, oil and gas operations, and mining regulatory functions undoubtedly cover some ground water protection activities not shown in the table. The illustration is intended only to show how the table might be used as a device to "inventory" state ground water activities. Each state, through an analysis of its own agency responsibilities in this manner, can identify its own specific areas of inadequacy in providing regulation and personnel for the protection of ground water.

TATE

TABLE I.

MANPOWER

14 INAGE LLS & MPS	15 ARTIFICIAL RECHARGE	16 DISPOSAL WELLS	17 OIL & GAS, SECONDARY RECOVERY	18 WATER SUPPLY WELLS	19 EXPLORATIVE & ABANDONED HOLES	20 MINING	21 GROUND WATER DEVELOPMENT
opulation.							
)							
$/10^6$ Pop.	2 M.D. /system	6 M.D./2 wells	2 M.D./5 proj./yr.	100 M.D./10^3 wells	10 M.D./100 units	4 M.D./10 mines	(see R.A. 18)**
$/10^6$ Pop.	10 M.D. /system	30 M.D./2 wells	5 M.D./5 proj./yr.	250 M.D./10^3 wells	20 M.D./100 units	20 M.D./10 mines	(see R.A. 18)**
$/10^6$ Pop.	2 M.D./system	2 M.D./2 wells	2 M.D./5 proj./yr.	100 M.D./10^3 wells	20 M.D./100 units	4 M.D./10 mines	(see R.A. 18)**
$/10^6$ Pop.	1 M.D./system	2 M.D./2 wells	2 M.D./5 proj./yr.	5 M.D./10^4 wells	2 M.D./100 units	2 M.D./10 mines	2 M.D./300 wells
$/10^6$ Pop.	2 M.D./system	4 M.D./2 wells	10 M.D./5 proj./yr.	25 M.D./10^4 wells	20 M.D./100 units	10 M.D./10 mines	10 M.D./300 wells
$/10^6$ Pop.	1 M.D./system	1 M.D./2 wells	2 M.D./5 proj./yr.	125 M.D./10^4 wells	10 M.D./100 units	2 M.D./10 mines	10 M.D./300 wells
$/10^6$ Pop.	1 M.D./system	2 M.D./2 wells	2 M.D./5 proj./yr.	5 M.D./10^4 wells	5 M.D./100 units	1 M.D./10 mines	5 M.D./300 wells
$/10^6$ Pop.	2 M.D./system	4 M.D./2 wells	12 M.D./5 proj./yr.	25 M.D./10^4 wells	20 M.D./100 units	5 M.D./10 mines	25 M.D./300 wells
$/10^6$ Pop.	1 M.D./system	1 M.D./2 wells	2 M.D./5 proj./yr.	125 M.D./10^4 wells	10 M.D./100 units	1 M.D./10 mines	10 M.D./300 wells
n population.							
)							
)							
$/10^6$ Pop.	4 M.D./system	10 M.D./2 wells	6 M.D./5 proj./yr.	101 M.D./10^3 wells	17 M.D./100 units	7 M.D./10 mines	7 M.D./300 wells
$/10^6$ Pop.	14 M.D./system	38 M.D./2 wells	27 M.D./5 proj./yr.	255 M.D./10^3 wells	60 M.D./100 units	35 M.D./10 mines	35 M.D./300 wells
$/10^6$ Pop.	4 M.D./system	4 M.D./2 wells	6 M.D./5 proj./yr.	135 M.D./10^3 wells	40 M.D./100 units	7 M.D./10 mines	20 M.D./300 wells

LL, GENERAL SOIL TYPES, ACTIVITY, LAND USE, ETC. THE ABOVE FIGURES ARE MERELY GENERALIZED GUIDELINES EQUIREMENTS FOR THE UTILIZATION OF THE PROPOSED GROUND WATER REGULATIONS, AND ARE IN ADDITION TO EMENTS FOR PRE-EXISTING PROBLEMS ARE NOT INCLUDED.

A

PERSONNEL REQUIREMENTS FOR A MODEL STATE GROUND WATER PROTECTION PROGRAM

AL	7 SLUDGES & EFFLUENTS	8 HIGHWAY SALTING	9 SURFACE WATER	10 AIR POLLUTION	11 HOLDING PONDS & LAGOONS	12 SEPTIC TANKS	13 STORAGE TANKS & LINES	14 DRAINAGE WELLS & SUMPS	15 ARTIFIC RECHAR
			2 Man-years, total, for all 21 Regulated Activities.						
		5 Man-years for States up to 2 million population. Increase 33% per million in excess of 2 million population.							
		2 Man-years	do 2	do do	(		do	)	
	50M.D./10⁶ Pop.	-0-	-0-	-0-	5 M.D./25 units	100 M.D./10³ units	2 M.D./10⁶ Pop.	2 M.D./10⁶ Pop.	2 M.D./sy
	120M.D./10⁶ Pop.	-0-	-0-	-0-	50M.D./25 units	500M.D./10³ units	5 M.D./10⁶ Pop.	5 M.D./10⁶ Pop.	10M.D./sy
	20M.D./10⁶ Pop.	-0-	-0-	-0-	2 M.D./25 units	100M.D./10³ units	5 M.D./10⁶ Pop.	5 M.D./10⁶ Pop.	2 M.D./sy
Pop.	50 M.D./10⁶ Pop.	10 M.D./10⁶ Pop.	30M.D./10⁶ Pop.	2 M.D./10⁶ Pop.	5 M.D./25 units	50M.D./10⁴ units	2M.D./10⁶ Pop.	2 M.D./10⁶ Pop.	1 M.D./sys
Pop.	50 M.D./10⁶ Pop.	30 M.D./10⁶ Pop.	30 M.D./10⁶ Pop.	5 M.D./10⁶ Pop.	5 M.D./25 units	25 M.D./10⁴ units	5 M.D./10⁶ Pop.	5 M.D./10⁶ Pop.	2 M.D./sy
Pop.	100M.D./10⁶ Pop.	20M.D./10⁶ Pop.	10 M.D./10⁶ Pop.	5 M.D./10⁶ Pop.	100 M.D./unit	125M.D./10⁴ units	5 M.D./10⁶ Pop.	5 M.D./10⁶ Pop.	1 M.D./sys
Pop.	100M.D./10⁶ Pop.	5 M.D./10⁶ Pop.	-0-	-0-	10 M.D./25 units	50 M.D./10⁴ units	5 M.D./10⁶ Pop.	10 M.D./10⁶ Pop.	1 M.D./syst
Pop.	1.5M.Yr./10⁶ Pop.*	30 M.D./10⁶ Pop.	10M.D./10⁶ Pop.	5 M.D./10⁶ Pop.	1 M.Yr./250 units	25M.D./10⁴ units	40M.D./10⁶ Pop.	20M.D./10⁶ Pop.	2 M.D./sys
Pop.	1 M.Yr./10⁶ Pop.	5 M.D./10⁶ Pop.	-0-	-0-	1 M.Yr./250 units	125M.D./10⁴ units	5 M.D./10⁶ Pop.	10 M.D./10⁶ Pop.	1 M.D./sys
		2 Man-years for States up to 2 million population. Increase 33% per million in excess of 2 million population.							
		5 Man-years	do	2 do do	(		do	)	
		2 Man-years	do	2 do do	(		do	)	
Pop.	200M.D./10⁶ Pop.	15 M.D./10⁶ Pop.	30 M.D./10⁶ Pop.	2 M.D./10⁶ Pop.	20 M.D./25 units	110M.D./10⁴ units	9 M.D./10⁶ Pop.	14 M.D./10⁶ Pop.	4 M.D./sys
Pop.	530M.D./10⁶ Pop.	60M.D./10⁶ Pop.	40 M.D./10⁶ Pop.	10 M.D./10⁶ Pop.	79 M.D./25 units	505M.D./10³ units	50M.D./10⁶ Pop.	30M.D./10⁶ Pop.	14 M.D./sys
Pop.	1.5 M.Yr./10⁶ Pop.	25 M.D./10⁶ Pop.	10 M.D./10⁶ Pop.	5 M.D./10⁶ Pop.	1.15 M.Yr./25 units	135 M.D./10³ units	15M.D./10⁶ Pop.	20M.D./10⁶ Pop.	4 M.D./sy

RE HIGHLY VARIABLE THROUGHOUT THE NATION. THESE MANPOWER ESTIMATES WILL DEPEND UPON RAINFALL, GENERAL SOIL
MODIFIED TO SUIT THE NEEDS OF EACH INDIVIDUAL APPLICATION. THESE ESTIMATES ARE BASED ONLY UPON THE REQUIREMENTS FOR
OF POLLUTION CONTROL. MANPOWER REQUIREMENTS ARE BASED UPON CURRENT ACTIVITIES ONLY, REQUIREMENTS FOR PRE

) 8 1

PERSONNEL
GROUND

Activities	1.	2	3	4	5	6	7	8	
INATION.	LANDFILLS, DUMPS & EXCAVATIONS	WASTEPILES & STOCKPILES	ANIMAL FEEDLOTS	FERTILIZER	PESTICIDES	ACCIDENTAL SPILLS	SLUDGES & EFFLUENTS	HIGHWAY SALTING	
ONAL									2
								5 Man-years for S	
								2 Man-years	
ISES.									
ONAL	50 M.D./10^6 Pop.	5 M.D./25 piles	10 M.D./200 lots	-0-	-0-	-0-	50 M.D./10^6 Pop.	-0-	
	1 M.Yr./10^6 Pop.*	50 M.D./25 piles	50 M.D./200 lots	-0-	-0-	-0-	120 M.D./10^6 Pop.	-0-	
	20 M.D./10^6 Pop.	10 M.D./25 piles	10 M.D./200 lots	-0-	-0-	-0-	20 M.D./10^6 Pop.	-0-	
OLLECTION.									
ONAL	50 M.D./10^6 Pop.	5 M.D./25 piles	10 M.D./200 lots	10 M.D./10^4 mi^2	10 M.D./10^4 mi^2	2 M.D./10^6 Pop.	50 M.D./10^6 Pop.	10 M.D./10^6 Pop.	3
	1 M.Yr./10^6 Pop.*	5 M.D./25 piles	50 M.D./200 lots	50 M.D./10^4 mi^2	30 M.D./10^4 mi^2	5 M.D./10^6 Pop.	50 M.D./10^6 Pop.	30 M.D./10^6 Pop.	3
	20 M.D./10^6 Pop.	10 M.D./25 piles	10 M.D./200 lots	50 M.D./10^4 mi^2	20 M.D./10^4 mi^2	5 M.D./10^6 Pop.	100 M.D./10^6 Pop.	20 M.D./10^6 Pop.	1
ONAL	100 M.D./10^6 Pop.	10 M.D./25 piles	10 M.D./200 lots	20 M.D./10^4 mi^2	20 M.D./10^4 mi^2	5 M.D./10^6 Pop.	100 M.D./10^6 Pop.	5 M.D./10^6 Pop.	
	1 M.Yr./10^6 Pop.*	20 M.D./25 piles	50 M.D./200 lots	22 M.D./10^3 mi^2	2 M.D./10^4 mi^2	40 M.D./10^6 Pop.	1.5 M.Yr./10^6 Pop.*	30 M.D./10^6 Pop.	1
	200 M.D./10^6 Pop.	20 M.D./25 piles	10 M.D./200 lots	40 M.D./10^4 mi^2	40 M.D./10^4 mi^2	5 M.D./10^6 Pop.	1 M.Yr./10^6 Pop.	5 M.D./10^6 Pop.	
ONAL								2 Man-years fo	
								5 Man-years	
								2 Man-years	
C'. & 'D'.									
ONAL	200 M.D./10^6 Pop.	20 M.D./25 piles	30 M.D./200 lots	30 M.D./10^4 mi^2	30 M.D./10^4 mi^2	7 M.D./10^6 Pop.	200 M.D./10^6 Pop.	15 M.D./10^6 Pop.	3
	3 M.Yr./10^6 Pop.*	75 M.D./25 piles	150 M.D./200 lots	522 M.D./10^3 mi^2	32 M.D./10^4 mi^2	45 M.D./10^6 Pop.	530 M.D./10^6 Pop.	60 M.D./10^6 Pop.	4
	1 M.Yr./10^6 Pop.	40 M.D./25 piles	30 M.D./200 lots	90 M.D./10^4 mi^2	60 M.D./10^4 mi^2	10 M.D./10^6 Pop.	1.5 M.Yr./10^6 Pop.	25 M.D./10^6 Pop.	

0 M.D.)

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* *OR per 200 population centers between 50 and 10,000 people.*

** *No additional manpower required beyond that designated in other activities.*

*NOTE: ALL ACTIVITIES ARE HIGHLY VARIABLE THROUGHOUT
WHICH MUST BE MODIFIED TO SUIT THE NEEDS OF E
OTHER ASPECTS OF POLLUTION CONTROL. MANP*

Regulated Activities *Manpower Function*	1. LANDFILLS, DUMPS & EXCAVATIONS	2 WASTEPILES & STOCKPILES	3 ANIMAL FEEDLOTS	4 FERTILIZER	5 PESTICIDES
A.-PLANNING & COORDINATION.					
SENIOR PROFESSIONAL					
PROFESSIONAL					
CLERICAL					
B.-PERMITS & LICENSES.					
SENIOR PROFESSIONAL	50 M.D. /10^6 Pop.	5 M.D. / 25 piles	10 M.D. /200 lots	-0-	-0-
PROFESSIONAL	1 M.Yr. /10^6 Pop.*	50 M.D. /25 piles	50 M.D./200 lots	-0-	-0-
CLERICAL	20 M.D. /10^6 Pop.	10 M.D./25 piles	10 M.D/200 lots	-0-	-0-
C.-MONITORING & DATA COLLECTION.					
SENIOR PROFESSIONAL	50 M.D. /10^6 Pop.	5 M.D./25 piles	10 M.D. /200 lots	10 M.D. / 10^4 mi.^{2}	10 M.D. / 10^4 mi.^{2}
PROFESSIONAL	1 M.Yr. /10^6 Pop.*	5 M.D./25 piles	50 M.D./200 lots	50 M.D. / 10^4 mi.^{2}	30 M.D. /10^4 mi.^{2}
CLERICAL	20 M.D. /10^6 Pop.	10 M.D./25 piles	10 M.D./200 lots	50 M.D./10^4 mi.^{2}	20 M.D./10^4 mi.^{2}
D.-ENFORCEMENT.					
SENIOR PROFESSIONAL	100 M.D./10^6 Pop.	10 M.D./25 piles	10 M.D./200 lots	20 M.D. /10^4 mi.^{2}	20 M.D. / 10^4 mi.^{2}
PROFESSIONAL	1 M.Yr./10^6 Pop.*	20 M.D./25 piles	50 M.D./200 lots	22 M.D./10^3 mi.^{2}	2 M.D./10^4 mi.^{2}
CLERICAL	200 M.D./10^6 Pop.	20 M.D./25 piles	10 M.D./200 lots	40 M.D./10^4 mi.^{2}	40 M.D./10^4 mi.^{2}
E.-RESEARCH.					
SENIOR PROFESSIONAL					
PROFESSIONAL					
CLERICAL					
F.- SUBTOTALS OF 'B', 'C' & 'D'.					
SENIOR PROFESSIONAL	200 M.D./10^6 Pop.	20 M.D./25 piles	30 M.D./200 lots	30 M.D./10^4 mi.^{2}	30 M.D./10^4 mi.^{2}
PROFESSIONAL	3 M.Yr./10^6 Pop.*	75 M.D./25 piles	150 M.D./200 lots	522 M.D./10^3 mi.^{2}	32 M.D./10^4 mi.^{2}
CLERICAL	1 M.Yr. /10^6 Pop.	40 M.D./25 piles	30 M.D./200 lots	90 M.D./10^4 mi.^{2}	60 M.D./10^4 mi.^{2}

M.D. = Man Days.
M.Yr. = Man Year (= 240 M.D.)

Scientific Notation (10^x);
10^3 = 10x10x10 = 1000, similarly,
10^6 = 1000,000 (one million)

* *OR per 200 population centers between 50 and 10,000 people.*

** *No additional manpower required beyond that designated in other activities.*

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OTHER

D

Regulated Activities *Manpower Function*	1. LANDFILLS, DUMPS & EXCAVATIONS	2 WASTEPILES & STOCKPILES	3 ANIMAL FEEDLOTS	4 FERTILIZER	5 PESTICIDES
A.-PLANNING & COORDINATION.					
SENIOR PROFESSIONAL					
PROFESSIONAL	←				
CLERICAL					
B.-PERMITS & LICENSES.					
SENIOR PROFESSIONAL					
PROFESSIONAL	*eGHIsm*	*eGHIm*	*AGh*	*AGhS*	*AGhsm*
CLERICAL					
C.-MONITORING & DATA COLLECTION.					
SENIOR PROFESSIONAL					
PROFESSIONAL	*CeGhIsm*	*CeGhIsm*	*ACeGhIs*	*ACeGhIs*	*ACeGhIsm*
CLERICAL					
D.-ENFORCEMENT.					
SENIOR PROFESSIONAL					
PROFESSIONAL	*eGhIsb*	*aeGhsb*	*AeGhb*	*aGhb*	*aGhb*
CLERICAL					
E.-RESEARCH.					
SENIOR PROFESSIONAL					
PROFESSIONAL	←				
CLERICAL					

NOTE:

Lower case letters
Capital letters ind

PERSONNEL REQUIREMENTS FOR A MODEL S
GROUND WATER PROTECTION PROGRAM

5 TICIDES	6 ACCIDENTAL SPILLS	7 SLUDGES & EFFLUENTS	8 HIGHWAY SALTING	9 SURFACE WATER	10 AIR POLLUTION	11 HOLDING PONDS & LAGOONS	12 SEPTIC TANKS	13 STORAGE TANKS & LINES	14 DRAI WELL SUM
						aceGls			
Ghsm		aeGHISm	a G s	e Ghl	G	aeGHIsm	ae GHIS	e G Hm	G h
Ghlsm	eGhlsm	CeGhlsm	CeGh	CGh	CGh	CeGhsm	CeGhs	CG h m	CGh
G hb	aeGhsb	aeGhlsb	Gb	e Ghb	Ghb	aeGhsb	eGhlsb	eGhb	Gh
						aceGHIs			

letters denote optional, but often beneficial, skill input.
ers indicate mandatory skill requirement input.

A/a - Agricultural En
C/c - Computer Specia
E/e - Civil or Sanitary E
G/g - Ground-water Geolo
B/b - Attorney, Legal A

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TABLE II.

L STATE
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PROFESSIONAL QUALIFICATIONS

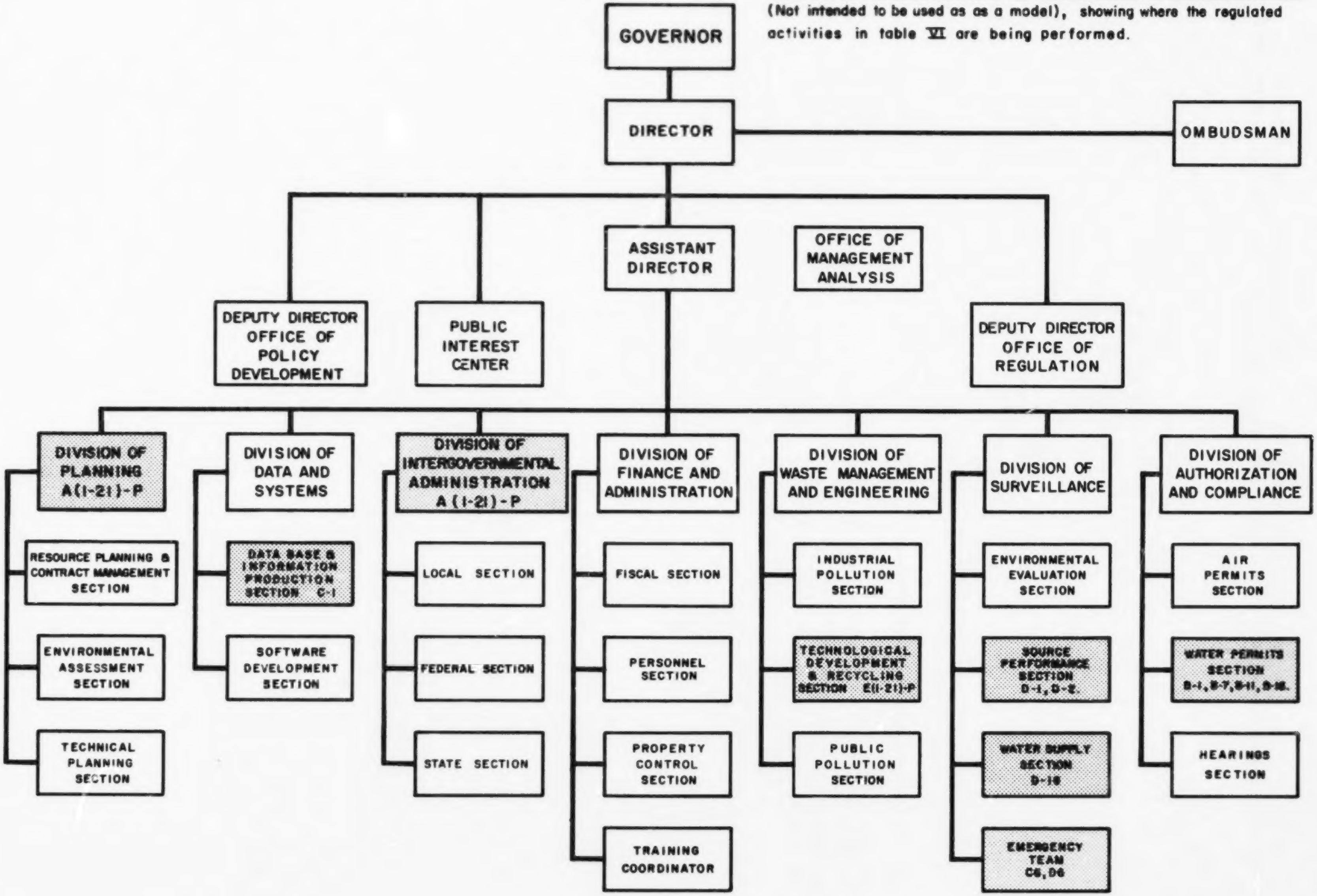
14 DRAINAGE WELLS & SUMPS	15 ARTIFICIAL RECHARGE	16 DISPOSAL WELLS	17 OIL & GAS, SECONDARY RECOVERY	18 WATER SUPPLY WELLS	19 EXPLORATIVE & ABANDONED HOLES	20 MINING	21 GROUND WATER DEVELOPMENT
Gh	*aGhls*	*Ghpm*	*Gp*	*eGH*	*G*	*G*	*G*
CGhls	*CGhp*	*CGpm*	*CGH*	*CG*	*CG*	*CG*	*CG*
Ghb	*eGhlsb*	*Ghpmb*	*Gpb*	*GHeb*	*Gb*	*Gb*	*Gb*

L E G E N D

ural Engineer	*H/h - Health Officer*
r Specialist	*L/l - Land Use Planner*
Sanitary Engineer	*P/p - Petroleum Engineer*
ater Geologist	*S/s - Soils Specialist*
, Legal Aide	*M/m - Mechanical Engineer*

TABLE III

Example of a common existing State E.P.A. Organization Structure. (Not intended to be used as as a model), showing where the regulated activities in table VI are being performed.


GOVERNOR
DIRECTOR
OMBUDSMAN
ASSISTANT DIRECTOR
OFFICE OF MANAGEMENT ANALYSIS
DEPUTY DIRECTOR OFFICE OF POLICY DEVELOPMENT
PUBLIC INTEREST CENTER
DEPUTY DIRECTOR OFFICE OF REGULATION
DIVISION OF PLANNING A(I-21)-P
RESOURCE PLANNING & CONTRACT MANAGEMENT SECTION
ENVIRONMENTAL ASSESSMENT SECTION
TECHNICAL PLANNING SECTION
DIVISION OF DATA AND SYSTEMS
DATA BASE & INFORMATION PRODUCTION SECTION C-I
SOFTWARE DEVELOPMENT SECTION
DIVISION OF INTERGOVERNMENTAL ADMINISTRATION A (I-21) - P
LOCAL SECTION
FEDERAL SECTION
STATE SECTION
DIVISION OF FINANCE AND ADMINISTRATION
FISCAL SECTION
PERSONNEL SECTION
PROPERTY CONTROL SECTION
TRAINING COORDINATOR
DIVISION OF WASTE MANAGEMENT AND ENGINEERING
INDUSTRIAL POLLUTION SECTION
TECHNOLOGICAL DEVELOPMENT & RECYCLING SECTION E(I-21)-P
PUBLIC POLLUTION SECTION
DIVISION OF SURVEILLANCE
ENVIRONMENTAL EVALUATION SECTION
SOURCE PERFORMANCE SECTION D-1, D-2.
WATER SUPPLY SECTION D-18
EMERGENCY TEAM C6, D6
DIVISION OF AUTHORIZATION AND COMPLIANCE
AIR PERMITS SECTION
WATER PERMITS SECTION D-1, D-7, D-11, D-16.
HEARINGS SECTION

Example of a common existing State Department of HEALTH Organization Structure.
(Not intended to be used as a model), showing where the regulated activities in table VI are being performed.

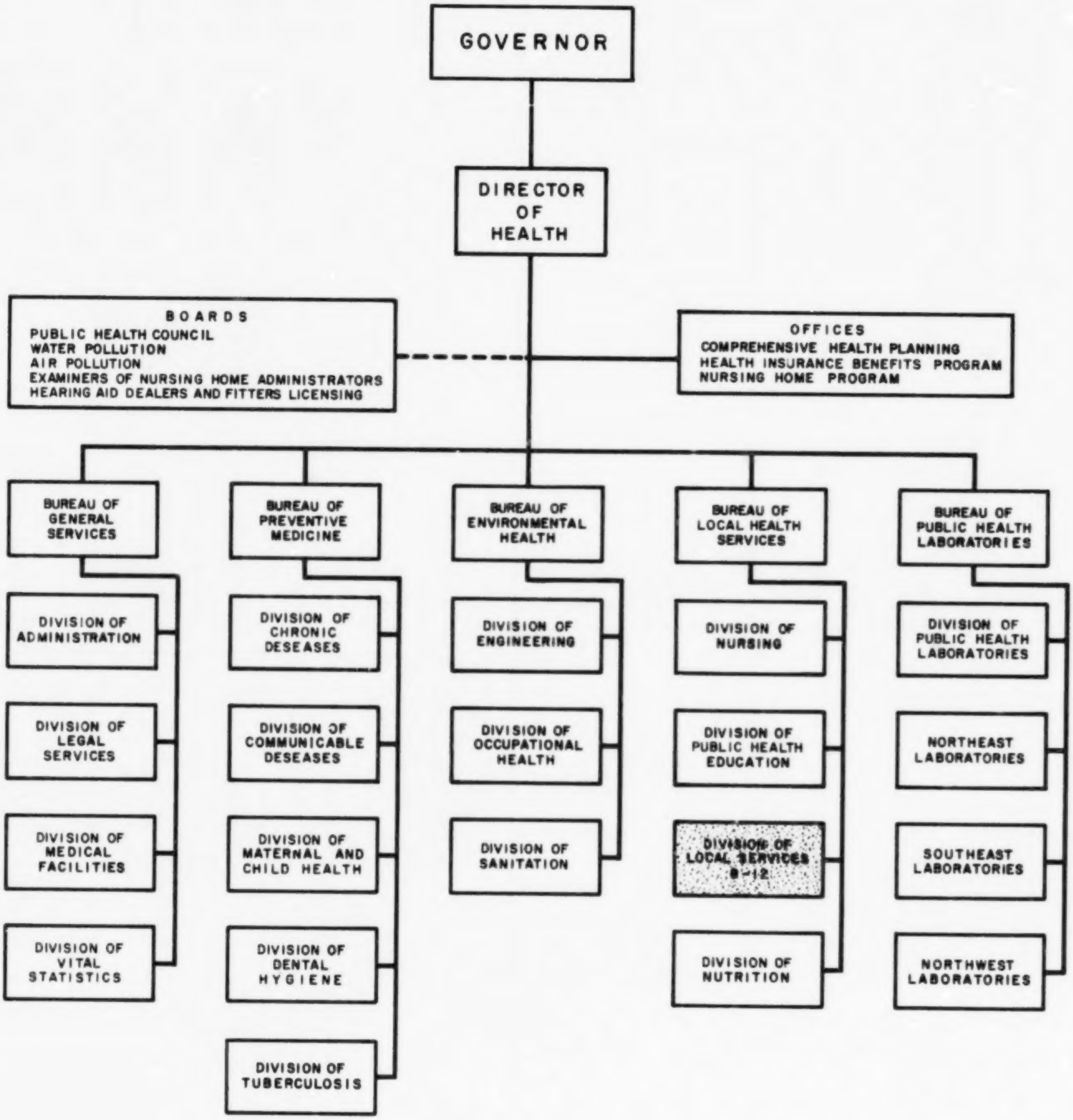
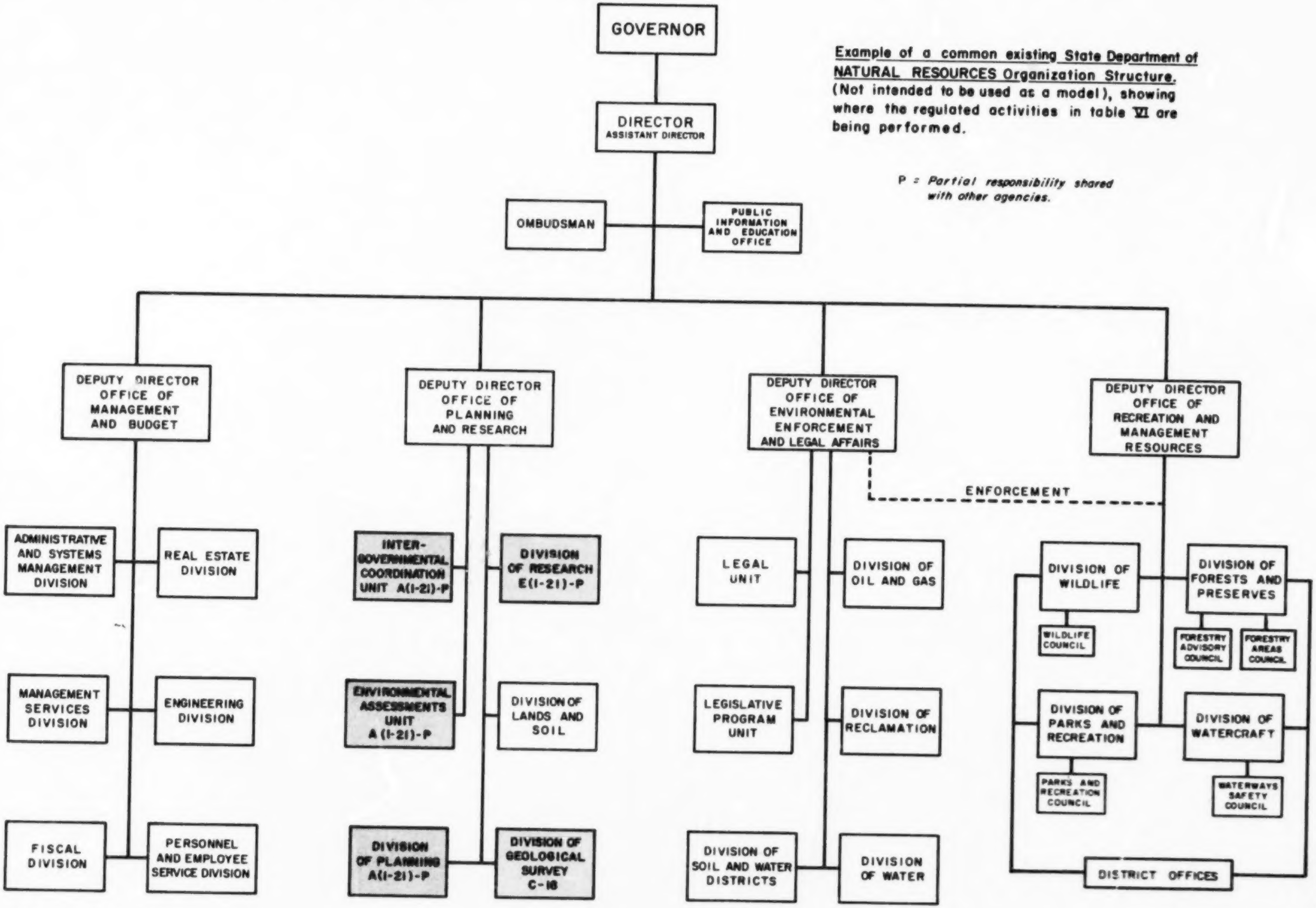

GOVERNOR
DIRECTOR OF HEALTH
BOARDS
PUBLIC HEALTH COUNCIL
WATER POLLUTION
AIR POLLUTION
EXAMINERS OF NURSING HOME ADMINISTRATORS
HEARING AID DEALERS AND FITTERS LICENSING
OFFICES
COMPREHENSIVE HEALTH PLANNING
HEALTH INSURANCE BENEFITS PROGRAM
NURSING HOME PROGRAM
BUREAU OF GENERAL SERVICES
DIVISION OF ADMINISTRATION
DIVISION OF LEGAL SERVICES
DIVISION OF MEDICAL FACILITIES
DIVISION OF VITAL STATISTICS
BUREAU OF PREVENTIVE MEDICINE
DIVISION OF CHRONIC DESEASES
DIVISION OF COMMUNICABLE DESEASES
DIVISION OF MATERNAL AND CHILD HEALTH
DIVISION OF DENTAL HYGIENE
DIVISION OF TUBERCULOSIS
BUREAU OF ENVIRONMENTAL HEALTH
DIVISION OF ENGINEERING
DIVISION OF OCCUPATIONAL HEALTH
DIVISION OF SANITATION
BUREAU OF LOCAL HEALTH SERVICES
DIVISION OF NURSING
DIVISION OF PUBLIC HEALTH EDUCATION
DIVISION OF LOCAL SERVICES 8-12
DIVISION OF NUTRITION
BUREAU OF PUBLIC HEALTH LABORATORIES
DIVISION OF PUBLIC HEALTH LABORATORIES
NORTHEAST LABORATORIES
SOUTHEAST LABORATORIES
NORTHWEST LABORATORIES

TABLE V


GOVERNOR
DIRECTOR
ASSISTANT DIRECTOR
OMBUDSMAN
PUBLIC INFORMATION AND EDUCATION OFFICE
DEPUTY DIRECTOR OFFICE OF MANAGEMENT AND BUDGET
ADMINISTRATIVE AND SYSTEMS MANAGEMENT DIVISION
REAL ESTATE DIVISION
MANAGEMENT SERVICES DIVISION
ENGINEERING DIVISION
FISCAL DIVISION
PERSONNEL AND EMPLOYEE SERVICE DIVISION
DEPUTY DIRECTOR OFFICE OF PLANNING AND RESEARCH
INTER-GOVERNMENTAL COORDINATION UNIT A(1-21)-P
DIVISION OF RESEARCH E(1-21)-P
ENVIRONMENTAL ASSESSMENTS UNIT A (1-21)-P
DIVISION OF LANDS AND SOIL
DIVISION OF PLANNING A(1-21)-P
DIVISION OF GEOLOGICAL SURVEY C-18
DEPUTY DIRECTOR OFFICE OF ENVIRONMENTAL ENFORCEMENT AND LEGAL AFFAIRS
LEGAL UNIT
DIVISION OF OIL AND GAS
LEGISLATIVE PROGRAM UNIT
DIVISION OF RECLAMATION
DIVISION OF SOIL AND WATER DISTRICTS
DIVISION OF WATER
ENFORCEMENT
DEPUTY DIRECTOR OFFICE OF RECREATION AND MANAGEMENT RESOURCES
DIVISION OF WILDLIFE
WILDLIFE COUNCIL
DIVISION OF FORESTS AND PRESERVES
FORESTRY ADVISORY COUNCIL
FORESTRY AREAS COUNCIL
DIVISION OF PARKS AND RECREATION
PARKS AND RECREATION COUNCIL
DIVISION OF WATERCRAFT
WATERWAYS SAFETY COUNCIL
DISTRICT OFFICES

Example of a common existing State Department of NATURAL RESOURCES Organization Structure. (Not intended to be used as a model), showing where the regulated activities in table VI are being performed.

P = Partial responsibility shared with other agencies.

Regulated Activities Manpower Function	1. LANDFILLS, DUMPS & EXCAVATIONS	2 WASTEPILES & STOCKPILES	3 ANIMAL FEEDLOTS	4 FERTILIZER	5 PESTICIDES	ACC S
A.-PLANNING & COORDINATION.						
SENIOR PROFESSIONAL						
PROFESSIONAL						
CLERICAL						
B.-PERMITS & LICENSES.						
SENIOR PROFESSIONAL	50 M.D./10^6 Pop.	5 M.D./25 piles	10 M.D./200 lots	-0-	-0-	
PROFESSIONAL	1 M.Yr./10^6 Pop.*	50 M.D./25 piles	50 M.D./200 lots	-0-	-0-	
CLERICAL	20 M.D./10^6 Pop.	10 M.D./25 piles	10 M.D./200 lots	-0-	-0-	
C.-MONITORING & DATA COLLECTION.						
SENIOR PROFESSIONAL	50 M.D./10^6 Pop.	5 M.D./25 piles	10 M.D./200 lots	10 M.D./10^4 mi.^{2}	10 M.D./10^4 mi.^{2}	2
PROFESSIONAL	1 M.Yr./10^6 Pop.*	5 M.D./25 piles	50 M.D./200 lots	50 M.D./10^4 mi.^{2}	30 M.D./10^4 mi.^{2}	5
CLERICAL	20 M.D./10^6 Pop.	10 M.D./25 piles	10 M.D./200 lots	50 M.D./10^4 mi.^{2}	20 M.D./10^4 mi.^{2}	5
D.-ENFORCEMENT.						
SENIOR PROFESSIONAL	100 M.D./10^6 Pop.	10 M.D./25 piles	10 M.D./200 lots	20 M.D./10^4 mi.^{2}	20 M.D./10^4 mi.^{2}	5
PROFESSIONAL	1 M.Yr./10^6 Pop.*	20 M.D./25 piles	50 M.D./200 lots	22 M.D./10^3 mi.^{2}	2 M.D./10^4 mi.^{2}	40
CLERICAL	200 M.D./10^6 Pop.	20 M.D./25 piles	10 M.D./200 lots	40 M.D./10^4 mi.^{2}	40 M.D./10^4 mi.^{2}	5
E.-RESEARCH.						
SENIOR PROFESSIONAL						
PROFESSIONAL						
CLERICAL						
F.- SUBTOTALS OF 'B.', 'C.' & 'D.'						
SENIOR PROFESSIONAL	200 M.D./10^6 Pop.	20 M.D./25 piles	30 M.D./200 lots	30 M.D./10^4 mi.^{2}	30 M.D./10^4 mi.^{2}	7
PROFESSIONAL	3 M.Yr./10^6 Pop.*	75 M.D./25 piles	150 M.D./200 lots	522 M.D./10^3 mi.^{2}	32 M.D./10^4 mi.^{2}	45
CLERICAL	1 M.Yr./10^6 Pop.	40 M.D./25 piles	30 M.D./200 lots	90 M.D./10^4 mi.^{2}	60 M.D./10^4 mi.^{2}	10

M.D. = Man Days.
M.Yr. = Man Year (= 240 M.D.)

Scientific Notation (10^x);
$10^3 = 10 \times 10 \times 10 = 1000$, similarly,
$10^6 = 1000,000$ (one million)

* *OR per 200 population centers between 50 and 10,000 people.*

** *No additional manpower required beyond that designated in other activities.*

NOTE: ALL ACTIVI
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PERSONNEL REQUIREMENTS FOR A MODEL S
GROUND WATER PROTECTION PROGRAM

5	6	7	8	9	10	11	12	13	
TICIDES	ACCIDENTAL SPILLS	SLUDGES & EFFLUENTS	HIGHWAY SALTING	SURFACE WATER	AIR POLLUTION	HOLDING PONDS & LAGOONS	SEPTIC TANKS	STORAGE TANKS & LINES	DR WE S
				2 Man-years, total, for all 21 Regulated Activities.					
			5 Man-years for States up to 2 million population. Increase 33% per million in excess of 2 million p						
			2 Man-years	*do 2*	*do do*	*(*		*do*	
-0-	*-0-*	*50M.D./10^6 Pop.*	*-0-*	*-0-*	*-0-*	*5 M.D./25 units*	*100 M.D./10^3 units*	*2 M.D./10^6 Pop.*	*2 M.*
-0-	*-0-*	*120M.D./10^6 Pop.*	*-0-*	*-0-*	*-0-*	*50M.D./25 units*	*500M.D./10^3 units*	*5 M.D./10^6 Pop.*	*5 M.D*
-0-	*-0-*	*20M.D./10^6 Pop.*	*-0-*	*-0-*	*-0-*	*2 M.D./25 units*	*100M.D./10^3 units*	*5 M.D./10^6 Pop.*	*5 M.D*
/10^4 mi.^{2}	*2 M.D./10^6 Pop.*	*50 M.D./10^6 Pop.*	*10 M.D./10^6 Pop.*	*30M.D./10^6 Pop.*	*2 M.D./10^6 Pop.*	*5 M.D./25 units*	*50M.D./10^4 units*	*2M.D./10^6 Pop.*	*2 M.*
/10^4 mi.^{2}	*5 M.D./10^6 Pop.*	*50 M.D./10^6 Pop.*	*30 M.D./10^6 Pop.*	*30 M.D./10^6 Pop.*	*5 M.D./10^6 Pop.*	*5 M.D./25 units*	*25 M.D./10^4 units*	*5 M.D./10^6 Pop.*	*5 M.D*
/10^4 mi.^{2}	*5 M.D./10^6 Pop.*	*100M.D./10^6 Pop.*	*20M.D./10^6 Pop.*	*10 M.D./10^6 Pop.*	*5 M.D./10^6 Pop.*	*100 M.D./unit*	*125M.D./10^4 units*	*5 M.D./10^6 Pop.*	*5 M.D*
/10^4 mi.^{2}	*5 M.D./10^6 Pop.*	*100M.D./10^6 Pop.*	*5 M.D./10^6 Pop.*	*-0-*	*-0-*	*10 M.D./25 units*	*50 M.D./10^4 units*	*5 M.D./10^6 Pop.*	*10 M.*
/10^4 mi.^{2}	*40M.D./10^6 Pop.*	*1.5M.Yr./10^6 Pop.**	*30 M.D./10^6 Pop.*	*10M.D./10^6 Pop.*	*5 M.D./10^6 Pop.*	*1 M.Yr./250 units*	*25M.D./10^4 units*	*40M.D./10^6 Pop.*	*20 M*
/10^4 mi.^{2}	*5 M.D./10^6 Pop.*	*1 M.Yr./10^6 Pop.*	*5 M.D./10^6 Pop.*	*-0-*	*-0-*	*1 M.Yr./250 units*	*125M.D./10^4 units*	*5 M.D./10^6 Pop.*	*10 M*
			2 Man-years for States up to 2 million population. Increase 33% per million in excess of 2 milli						
			5 Man-years	*do*	*2 do do*	*. (*		*do*	
			2 Man-years	*do*	*2 do do*	*. (*		*do*	
/10^4 mi.^{2}	*7 M.D./10^6 Pop.*	*200M.D./10^6 Pop.*	*15 M.D./10^6 Pop.*	*30 M.D./10^6 Pop.*	*2 M.D./10^6 Pop.*	*20 M.D./25 units*	*110M.D./10^4 units*	*9 M.D./10^6 Pop.*	*14 M.*
/10^4 mi.^{2}	*45 M.D./10^6 Pop.*	*530M.D./10^6 Pop.*	*60M.D./10^6 Pop.*	*40 M.D./10^6 Pop.*	*10 M.D./10^6 Pop.*	*79 M.D./25 units*	*505M.D./10^3 units*	*50M.D./10^6 Pop.*	*30M*
/10^4 mi.^{2}	*10 M.D./10^6 Pop.*	*1.5 M.Yr./10^6 Pop.*	*25 M.D./10^6 Pop.*	*10 M.D./10^6 Pop.*	*5 M.D./10^6 Pop.*	*1.15 M.Yr./25 units*	*135M.D./10^3 units*	*15M.D./10^6 Pop.*	*20M*

L E G E N D

E.P.A. NATURAL RESOURCES DEPT. OF H

ALL ACTIVITIES ARE HIGHLY VARIABLE THROUGHOUT THE NATION. THESE MANPOWER ESTIMATES WILL DEPEND UPON RAINF
WHICH MUST BE MODIFIED TO SUIT THE NEEDS OF EACH INDIVIDUAL APPLICATION. THESE ESTIMATES ARE BASED ONLY UPON THE
OTHER ASPECTS OF POLLUTION CONTROL. MANPOWER REQUIREMENTS ARE BASED UPON CURRENT ACTIVITIES ONLY, REQU

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TABLE VI.

HYPOTHETICAL EXAMPLE OF AGENCY RESPONSIBILITY

E 8	14 DRAINAGE WELLS & SUMPS	15 ARTIFICIAL RECHARGE	16 DISPOSAL WELLS	17 OIL & GAS, SECONDARY RECOVERY	18 WATER SUPPLY WELLS	19 EXPLORATIVE & ABANDONED HOLES	20 MINING	21 GROUND WATER DEVELOPMENT
2 million population.								
		)						
Pop.	2 M.D./10^6 Pop.	2 M.D. /system	6M.D./2 wells	2 M.D./5 proj./yr.	100M.D./10^3 wells	10 M.D./100 units	4 M.D./10 mines	(see R.A. 18)**
Pop.	5 M.D./10^6 Pop.	10 M.D. /system	30M.D./2 wells	5 M.D./5 proj./yr.	250 M.D./10^3 wells	20M.D./100 units	20 M.D./10 mines	(see R.A. 18)**
Pop.	5 M.D./10^6 Pop.	2 M.D./system	2M.D./2 wells	2M.D./5 proj./yr.	100 M.D./10^3 wells	20M.D./100 units	4 M.D./10 mines	(see R.A. 18)**
Pop.	2 M.D./10^6 Pop.	1 M.D./system	2 M.D./2 wells	2M.D./5 proj./yr.	5 M.D./10^4 wells	2 M.D./100 units	2 M.D./10 mines	2 M.D./300 wells
Pop.	5 M.D./10^6 Pop.	2 M.D./system	4 M.D./2 wells	10M.D./5 proj./yr.	25 M.D./10^4 wells	20 M.D./100 units	10 M.D./10 mines	10 M.D./300 wells
Pop.	5 M.D./10^6 Pop.	1 M.D./system	1 M.D./2 wells	2 M.D./5 proj./yr.	125 M.D./10^4 wells	10 M.D./100 units	2 M.D./10 mines	10 M.D./300 wells
Pop.	10 M.D./10^6 Pop.	1 M.D./system	2 M.D./2 wells	2 M.D./5 proj./yr.	5 M.D./10^4 wells	5 M.D./100 units	1 M.D./10 mines	5 M.D./300 wells
Pop.	20M.D./10^6 Pop.	2 M.D./system	4 M.D./2 wells	12M.D./5 proj./yr.	25M.D./10^4 wells	20M.D./100 units	5M.D./10 mines	25M.D./300 wells
Pop.	10 M.D./10^6 Pop.	1 M.D./system	1 M.D./2 wells	2 M.D./5 proj./yr.	125M.D./10^4 wells	10M.D./100 units	1 M.D./10 mines	10M.D./300 wells
f 2 million population.								
		)						
		)						
Pop.	14 M.D./10^6 Pop.	4 M.D./system	10 M.D./2 wells	6M.D./5 proj./yr.	101 M.D./10^3 wells	17 M.D./100 units	7 M.D./10 mines	7 M.D./300 wells
Pop.	30M.D./10^6 Pop.	14 M.D./system	38 M.D./2 wells	27M.D./5 proj./yr.	255M.D./10^3 wells	60M.D./100 units	35 M.D./10 mines	35M.D./300 wells
Pop.	20M.D./10^6 Pop.	4 M.D./system	4 M.D./2 wells	6 M.D./5 proj./yr.	135M.D./10^3 wells	40M.D./100 units	7 M.D./10 mines	20M.D./300 wells

OF HEALTH

N RAINFALL, GENERAL SOIL TYPES, ACTIVITY, LAND USE, ETC. THE ABOVE FIGURES ARE MERELY GENERALIZED GUIDELINES
PON THE REQUIREMENTS FOR THE UTILIZATION OF THE PROPOSED GROUND WATER REGULATIONS, AND ARE IN ADDITION TO
Y, REQUIREMENTS FOR PRE-EXISTING PROBLEMS ARE NOT INCLUDED.

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